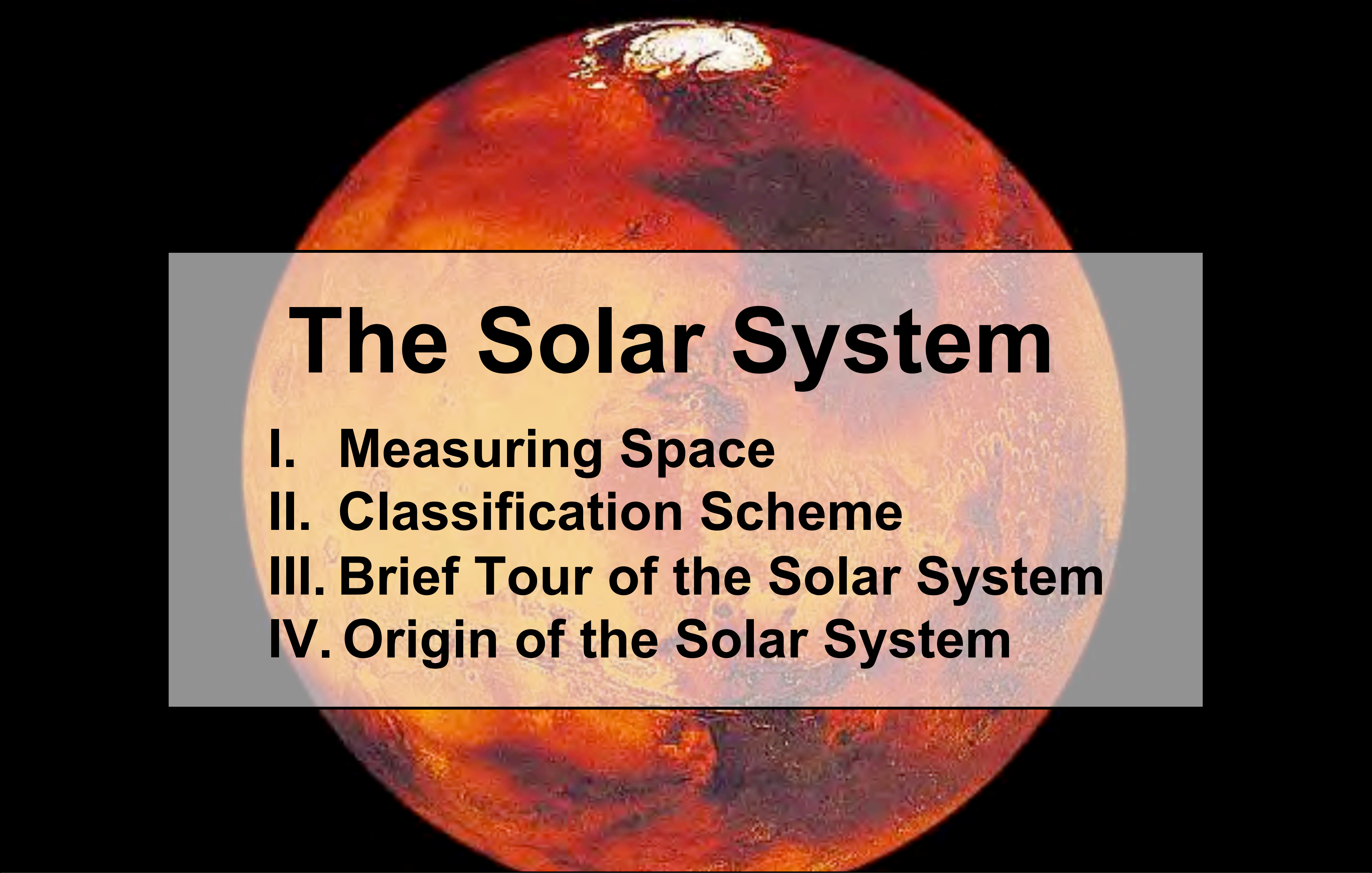


The Solar System

I. Measuring Space
II. Classification Scheme
III. Brief Tour of the Solar System
IV. Origin of the Solar System

iMSS Integrated Middle School Science Partnership
NSF
CALIFORNIA STATE UNIVERSITY EAST BAY
ALAMEDA COUNTY OFFICE OF EDUCATION

Why are we so interested in what is outside our own planet?

What can we hope to find on other worlds?

Our search for the answer to these sorts of questions are not only in the realm of science but also literature, religion and philosophy.

As scientists:

We hope to understand the origin and evolution of our world.

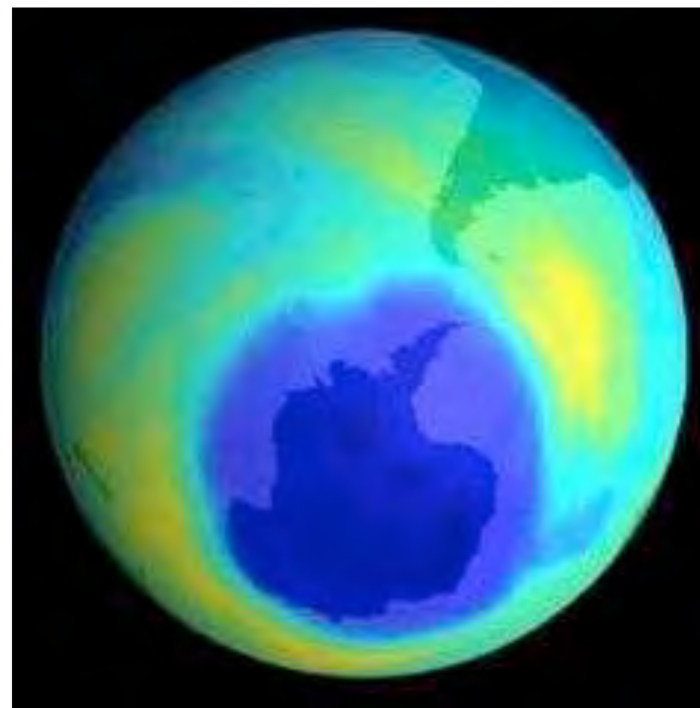
We want to understand the structure and climates of other worlds to see what they tell us about Earth.

Ultimately, many want to use this knowledge to live more successfully on our own planet - impacting our environment as little as possible.

Our exploration of space has given us two new perspectives:

1. *Environmental perspective* — once we were able to see an image how **small and fragile our planet appears from space**, it has change our perspective of a planet with infinite resources to one with finite resources.

Space-based platforms for observing and studying our planet have given us a new perspective that previous generation never had.



NASA

2. *Cosmic perspective* — although we recognize that we have evolved on a finite planet, we now recognize that **we live in a much larger environment**.

Just beyond the thin layer of our atmosphere, is the edge of interplanetary space.

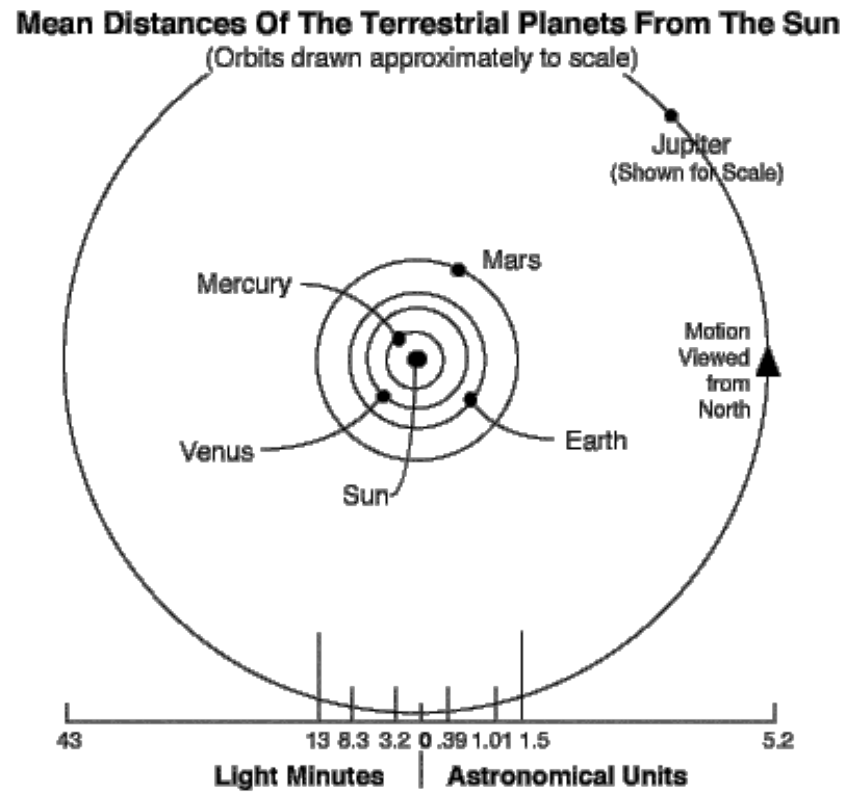
As an example, we know that impacts large enough to end our civilization occur on a timescale of roughly every 10^4 years.

That means that a global technological civilization cannot survive more than ~10,000 years — unless it develops the means to alter the orbits of interplanetary debris.

I. Measuring Space

Distances

Average distance between the Earth and sun is ~150,000,000 km — this distance has been chosen as an *astronomical unit* (AU).



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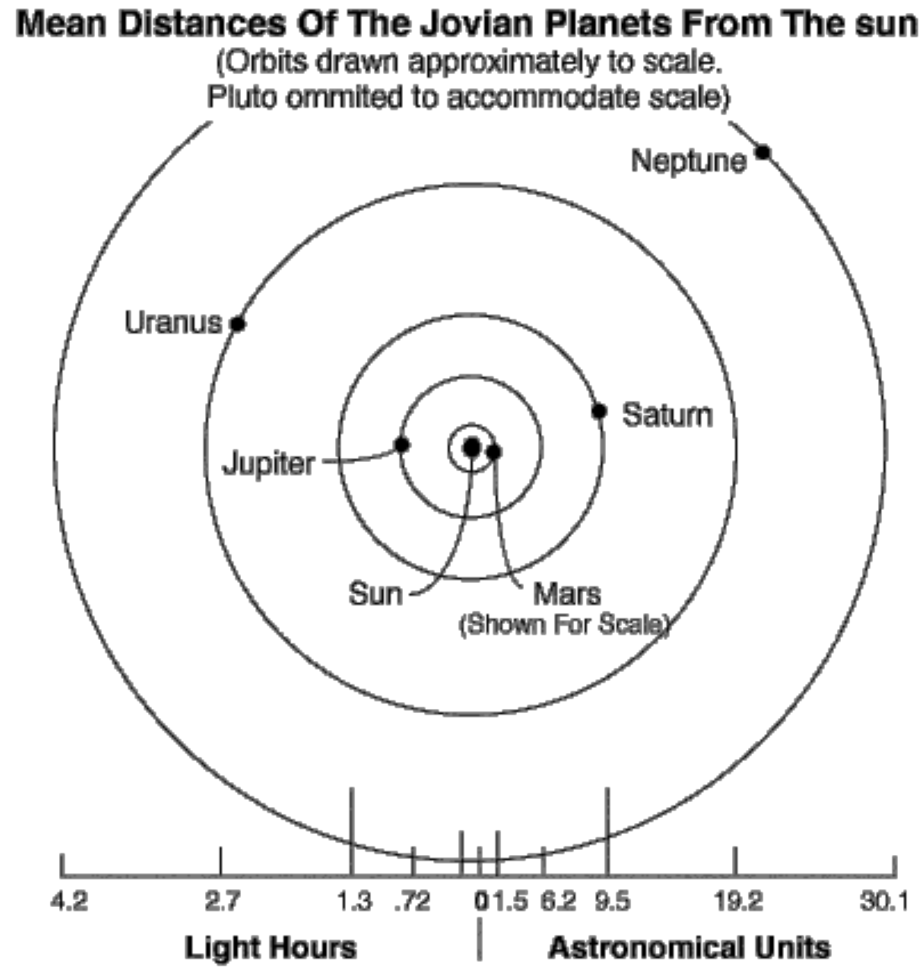
It is important to understand that this is the average distance since the Earth's orbit is not perfectly circular but is an ellipse. The actual distance varies by ~1.7% — nearly circular.

This unit is very convenient for measuring distances in our solar system. For example, the average distance between the sun and Venus is ~0.7 AU. The average distance between the sun and Pluto is ~39.44 AU. We can see that the orbit of Pluto is fairly eccentric in that its orbit carries it as close as 29.64 AU and as far away as 49.24 AU.

Another convenient way to measure great distances is by reference to the distance that light will travel in a certain amount of time.

Light travels in a vacuum at 299,458 km/sec. Thus we could say that a *light-second* is ~300,000 km.

It takes light 8.3 minutes to travel from the Sun to the Earth. Thus, we could say that the distance between the Earth and the Sun is ~8.3 *light-minutes*.



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Pluto would have a distance from the sun of ~5.5 light-hours!

The distance between stars is much greater and it is not reasonable to give their distances in terms of astronomical units. A *light-year* is the distance that light travels in space in one year.

Andromeda Galaxy NASA

1 light-year = 9,460,528,404,846 km
= 5,878,499,812,499 miles
= 63,240 AU

The closest star to our own is Proxima Centauri which is 4.2 light-years or ~39,900,000,000,000 km.
The Andromeda Galaxy is ~2.5 million light years from Earth.

Mass

In planetary science, the mass of an object is an important parameter.

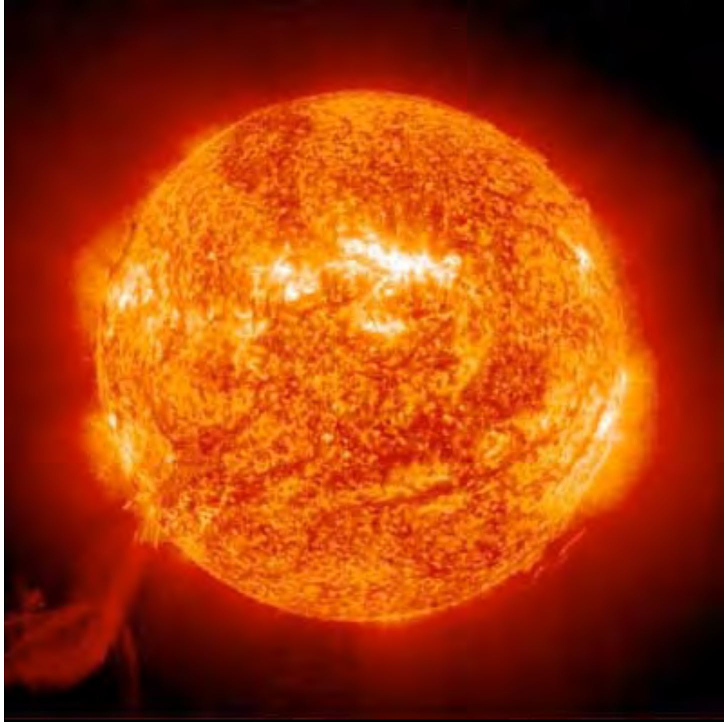
Typically, for solar system objects these data are reported in terms of the familiar kilogram. For example, the mass of Jupiter is 1.90×10^{27} kg.

However, in comparing the relative masses of stars, astronomers commonly use the mass of our Sun as a benchmark, developing a unit called a *solar mass* ($\odot$).

The mass of the Sun is 1.9×10^{30} kg.

The super massive star Eta Carinae is ~150$\odot$. The mass of Proxima Centari is 0.123$\odot$.

Jupiter would be ~0.001$\odot$.



II. Classification Scheme

Until recently, our solar system contained nine planets.

Mnemonic device for remembering the order of the planets are

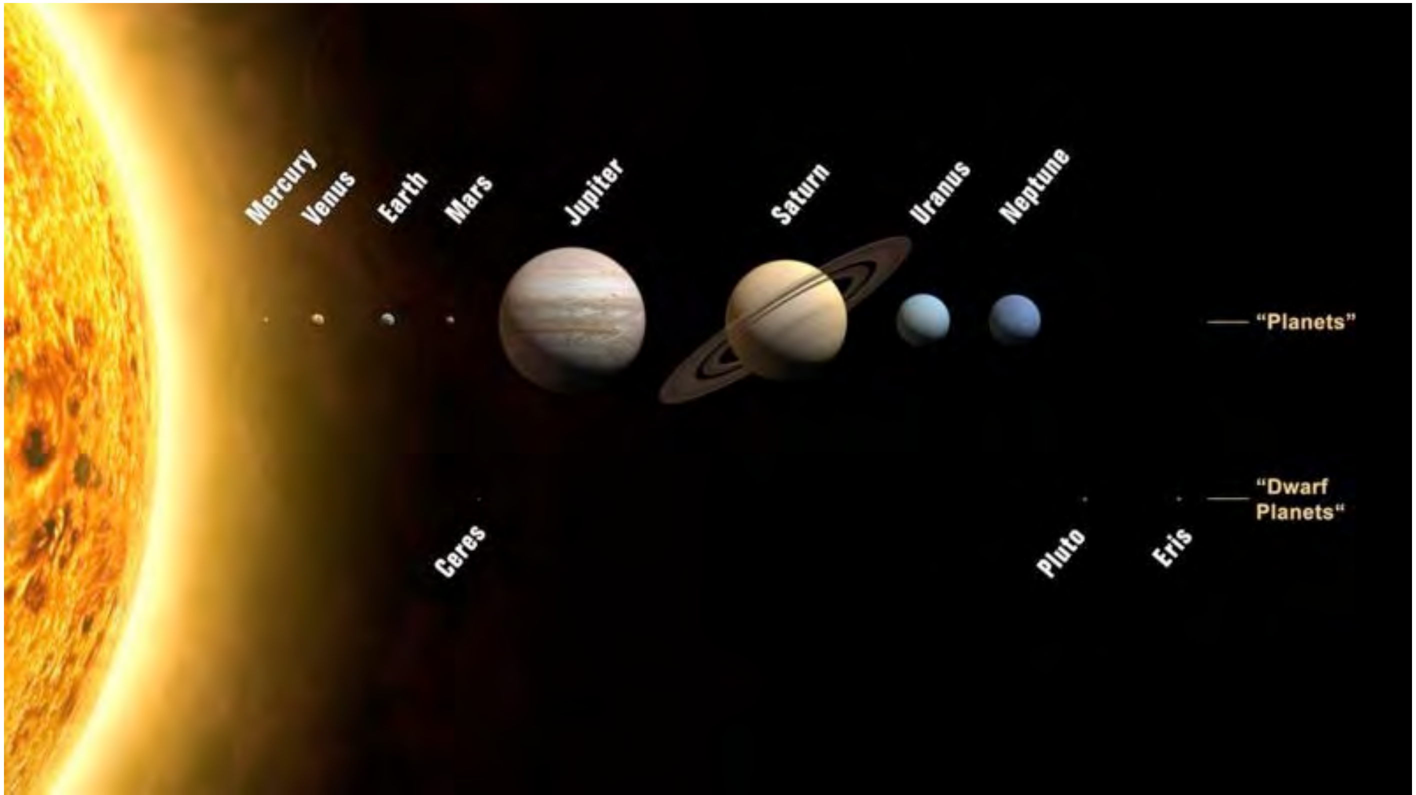
"My Very Excellent Mother Just Served Us Nine Pizzas. "

Most students have difficulty remembering the order in the neighborhood of Uranus. *SUN* is an easy way to remember the order Saturn-Uranus-Neptune.

The XXVIth General Assembly of the International Astronomical Union (IAU) redefined the nomenclature used to describe the solar system. Objects that orbit the Sun are classified as

- Planets
- Dwarf Planets
- Small Solar System Objects

There are 8 planets — Pluto was reassigned as a *dwarf planet*.



International Astronomical Union

What is a planet?

The word *planet* comes from the Greek for *wanderer*. This refers to the fact that the planets move across the sky while the stars remain stationary.

NASA/JPL

To the ancient Greeks, a planet was any of the seven bodies that changed position from day to day. The planets included the Sun, moon, and the 5 visible planets.

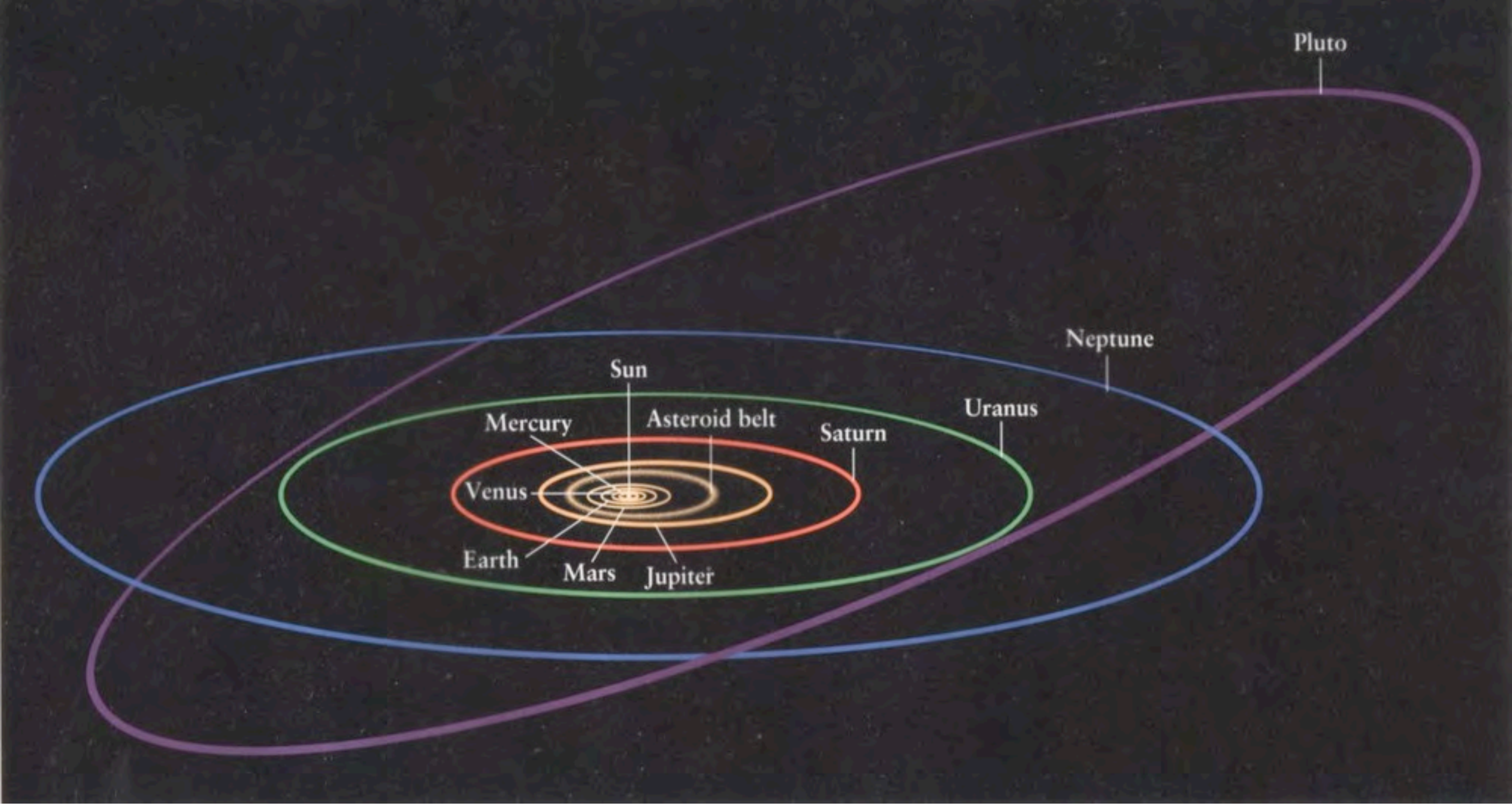
A *planet* (as defined by the IAU) is a celestial body orbiting a star or stellar remnant that is massive enough to be rounded by its own gravity, not massive enough to cause thermonuclear fusion, and has cleared its neighboring region of planetesimals.

The arguments that some astronomers use to support the view that Pluto should not be considered a planet include:

1. Recently (1990's), a large number of asteroids and comet nuclei have been discovered in the same region (Kuiper belt). Some of these are quite large and approach the size of Pluto.

2. Pluto is very small compared to the other planets. In fact, Pluto is about half the size of our own moon; seven other moons are larger than Pluto.

New Horizons,, NASA



3. The orbit of Pluto crosses inside that of Neptune — its very eccentric orbit is more like an asteroid or comet than a planet.

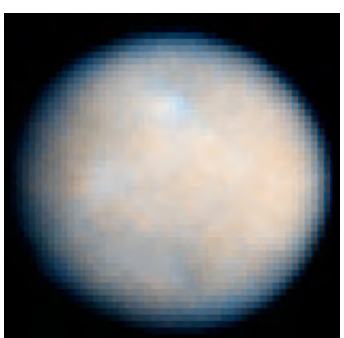
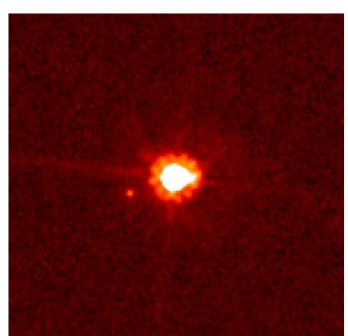
4. The orbit of Pluto is inclined to the plane of the solar system — this is also similar in behavior to asteroids and comets.

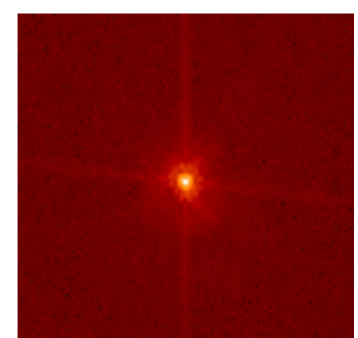
Dwarf Planets

There are currently 5 dwarf planets in our solar system:

- •Pluto (largest object in the Kuiper belt).
- •Ceres (largest object in the asteroid)
- •Eris (largest object in the scattered disk)
- •Haumea (Kuiper belt)
- •Makemake (Kuiper belt)

A *dwarf planet* (as defined by the IAU) is a celestial body orbiting the Sun that is massive enough to be rounded by its own gravity but which has not cleared its neighboring region of planetesimals and is not a satellite. The definition of dwarf planets only applies to our Solar System.



Images from NASA

At least another 42 discovered objects in the Solar System may eventually be classified as *dwarf planets*.

Martin Kornmesser, IAU


NASA HST

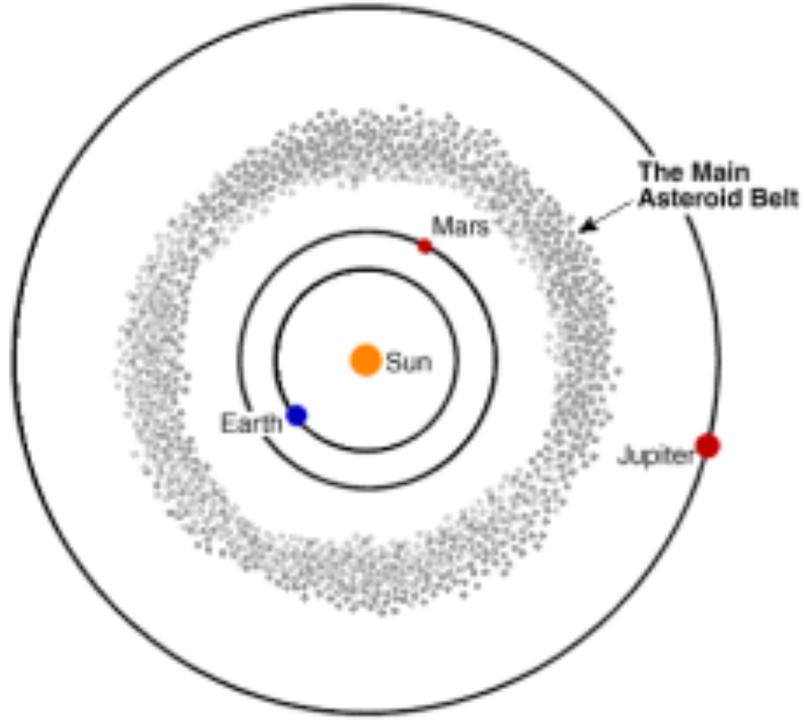
The asteroid Vesta does not appear to be rounded (appears to deviate from hydrostatic equilibrium), but this may be due to a large impact that occurred after it solidified.

When the outer reaches of the solar system are more completely explored, there may be thousands of *dwarf planets*.

Small Solar System Bodies

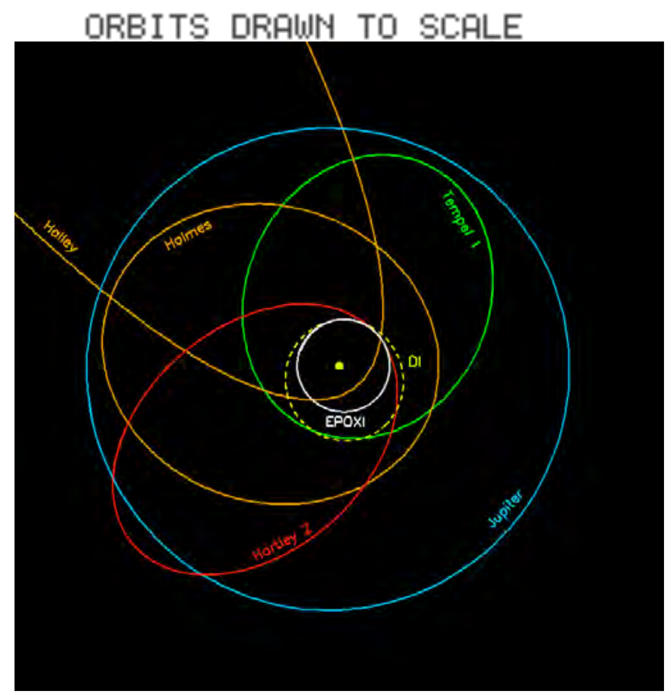
Small Solar System Bodies (SSSB, as defined by the IAU) are objects in the Solar System that are neither *planets* nor *dwarf planets* - this includes comets, most asteroids and trans-Neptunian objects.

This definition excludes satellites.



NASA/Goddard Space Flight Center

The orbits of several comets are shown in the bottom image.

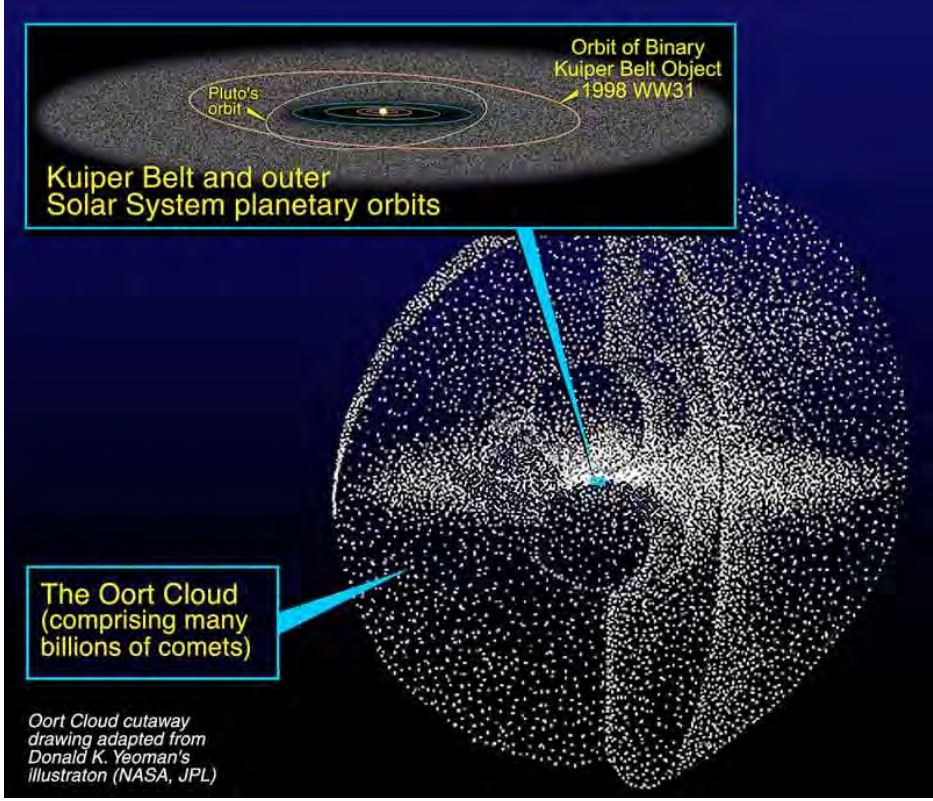


Credit: NASA/JPL-Caltech/UMD/GSFC/Tony Farnham

Most *Small Solar System Bodies* are found several regions:

Asteroid belt - region of rocky and icy bodies between the orbit of Mars and Jupiter. Vesta is found in the *asteroid belt*.

Kuiper belt - a disk-shaped region extending from the orbit of Neptune (at 30 AU) to approximately 55 AU from the Sun consisting mostly of icy objects. Pluto is a Kuiper belt object.

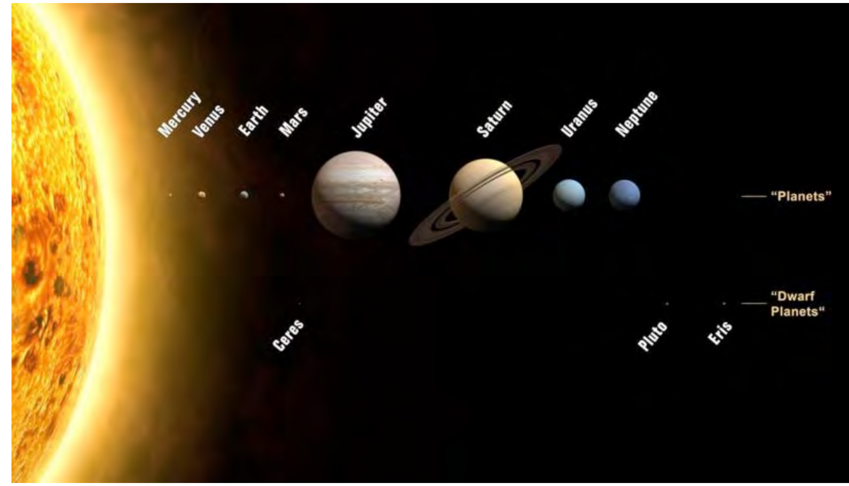


Scattered disk - thinly populated disk-shaped region of icy bodies that overlaps with the outer Kuiper belt and extends out to the Oort cloud. Eris is a *scattered disk* object.

Oort cloud - a spherical cloud of comets extending ~50,000 AU (nearly a light-year) from the Sun.

The planets fall into two main groups:

1. *Terrestrial* (Earth-like) planets: Mercury, Venus, Earth & Mars
2. *Jovian* (Jupiter-like) planets or *gas giants*: Jupiter, Saturn, Uranus & Neptune



International Astronomical Union

How do the terrestrial and Jovian planets differ?

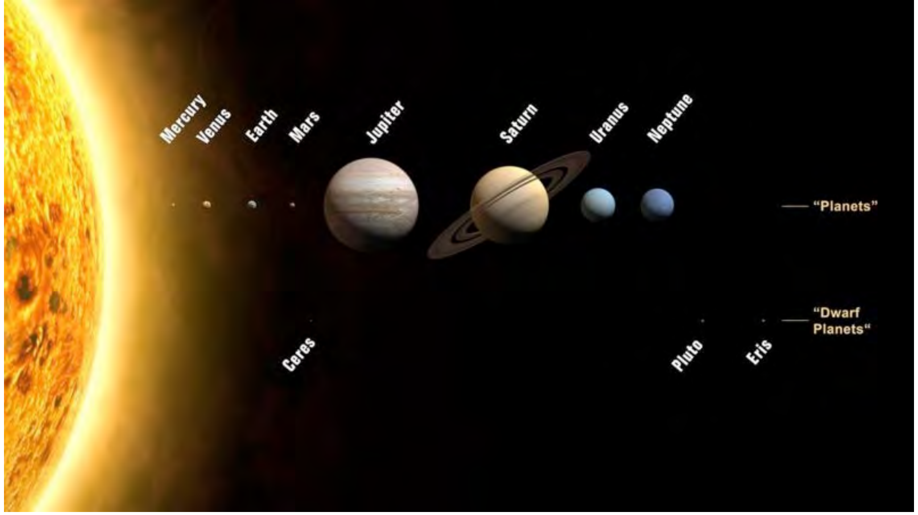
1. Size. The largest terrestrial planet is only 1/4 the size of the smallest Jovian planet. The figure to the right shows the relative sizes of the planets.

2. Density. The average density of the terrestrial planets is ~5 g/cm^3, whereas the Jovian planets have densities that average ~1.5 g/cm^3.

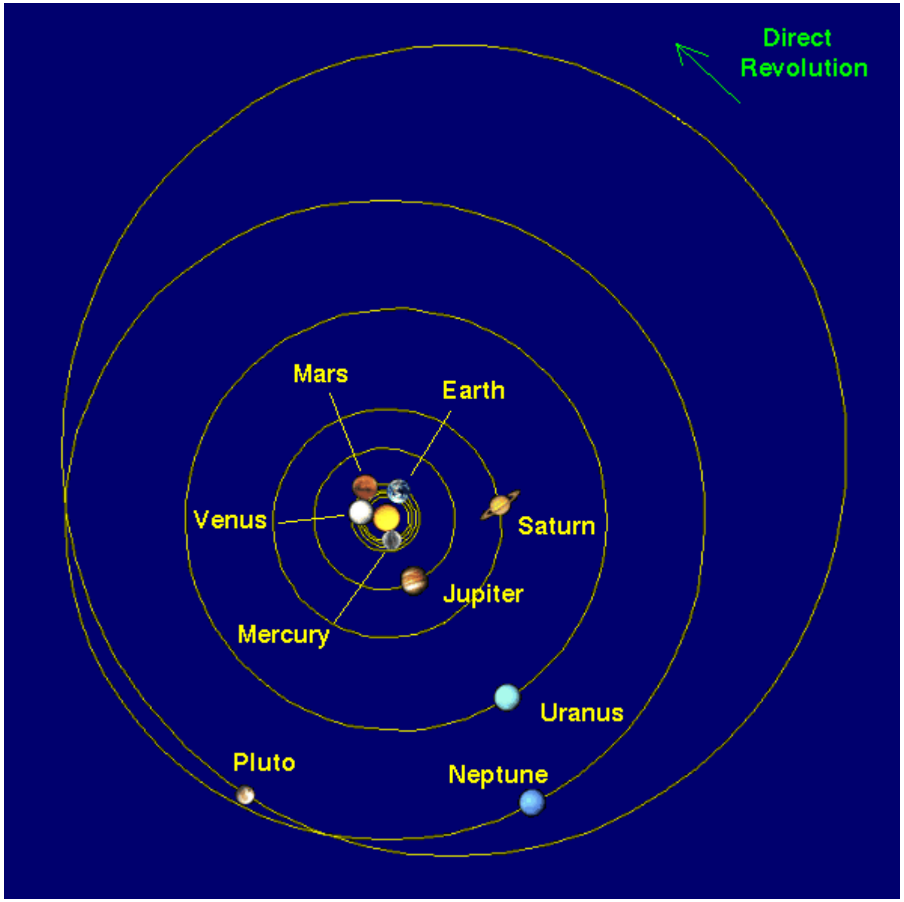
3. Composition: The terrestrial planets are composed of rocky and metallic material with minor amounts of gases. The Jovian planets contain a large percentage of gases (H and He) and ices (water ammonia and methane).

4. Atmosphere. The Jovian planets have very thick atmospheres (composed of light gases such as H and He). By comparison, the terrestrial planets have comparatively meager atmospheres (if any) of heavier gases (N_2, CO_2, and H_2O).

5. Location. The terrestrial planets are located in the inner solar system whereas the Jovian planet represent the farthest reaches of our solar system. In addition, the orbits of the terrestrial planets are much more closely spaced.



International Astronomical Union



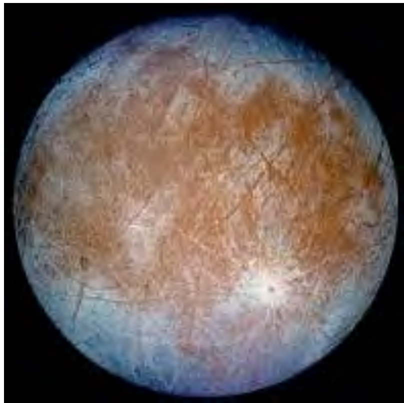
Some more definitions:

Satellite — any body in orbit around another larger body. At least 144 (depends on who’s counting) have been discovered in our solar system.

Asteroid — a small planetary body composed mostly of rock or metal. Most asteroids are found in a belt between the orbits of Mars and Jupiter. Asteroids have diameters less than ~1000 km.

Comet — an ice-rich planetary body that emits an observable gas trail as it is warmed by the Sun. Comets spend most of their time in the outer solar system far beyond the asteroid belt.

World — a term that has recently become more popular to describe planets and satellites that are large enough to have a distinct geologic characteristics.



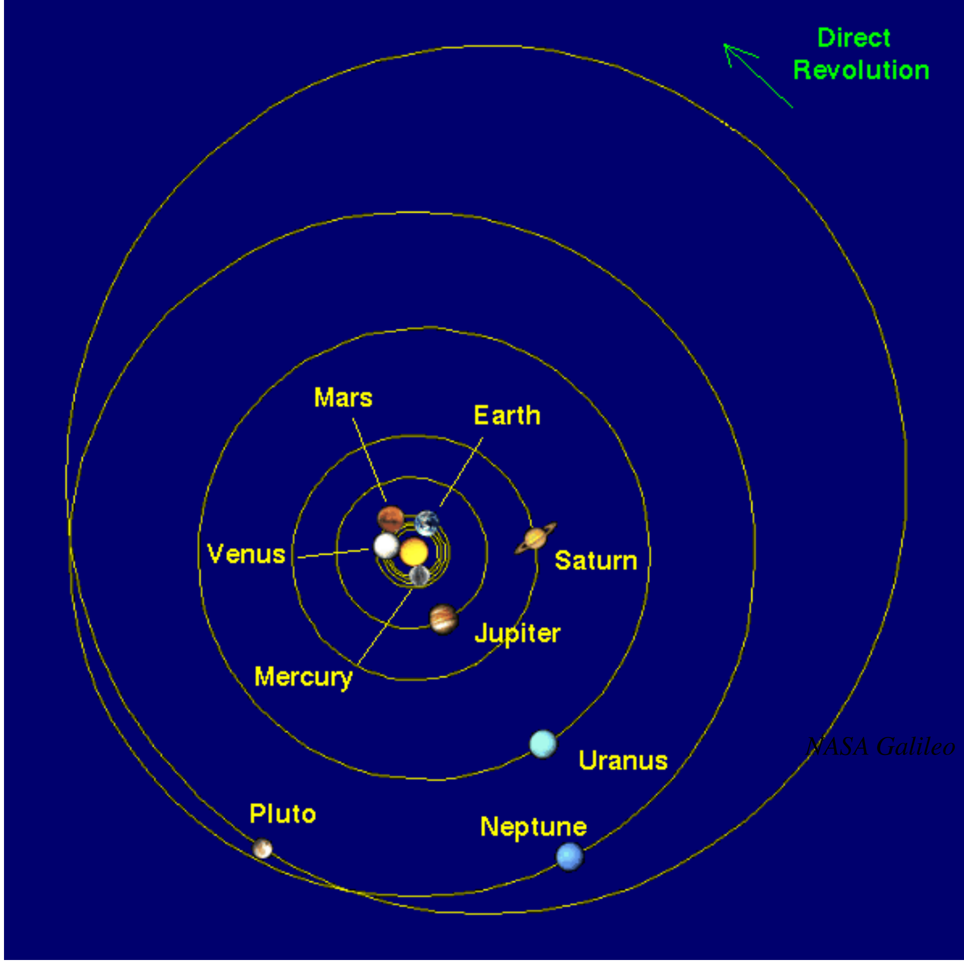
Images from NASA

Rotation describes how a planet spins on its axis.

In addition, to rotating, planets travel around the sun on a path called an *orbit*.

Revolution describes the movement of a planet along its orbit around the Sun.

The *period of revolution* is the amount of time it takes for a planet to complete one orbital revolution. On Earth, the period of revolution is 1 year (365 days).



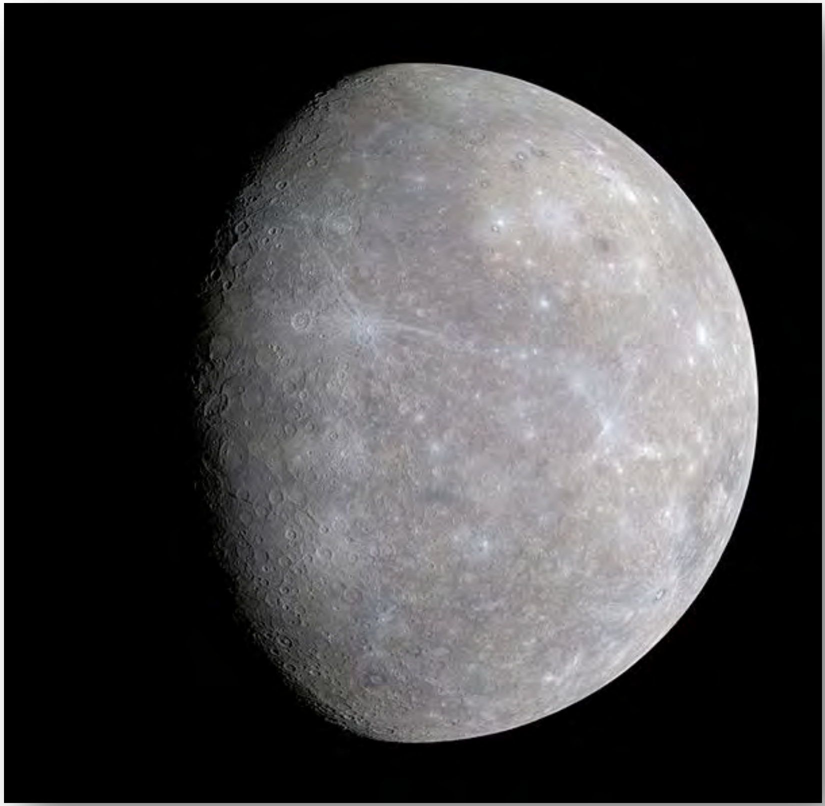
III. Brief Tour of the Solar System

Mercury

Mercury is the smallest planet and is closest to the Sun.

It is so close to the Sun that it is difficult to observe from Earth. It can only be seen at twilight, near the Sun.

mean distance from Sun	0.38 AU
radius	2439.7 km 0.38⊕
mass	3.30×10^{23} kg 0.055⊕
density	5.42 g/cm^3
# moons	0



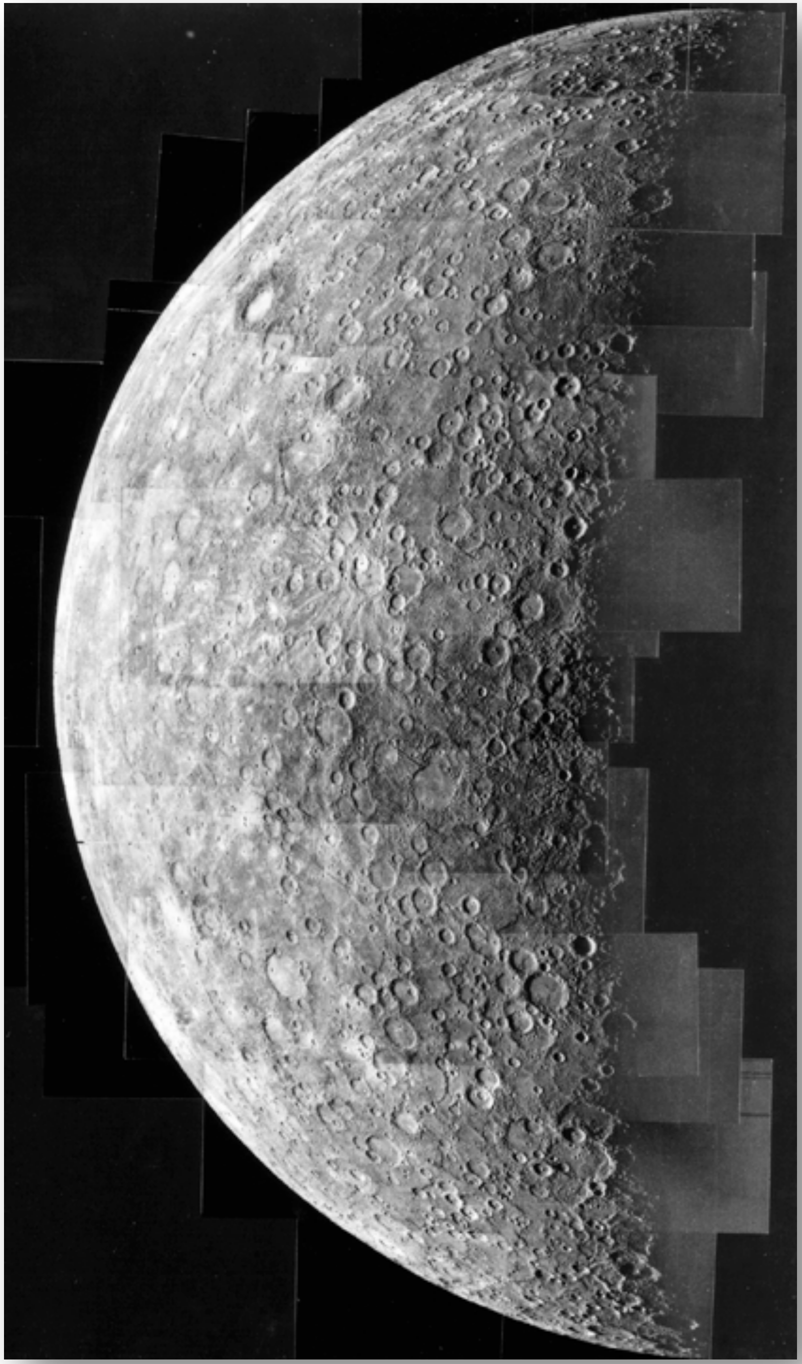
NASA Messenger

Mercury essentially has no detectable atmosphere — too small to retain one.

The surface temp ranges from -173 on the dark side to 427°C in direct sunlight.

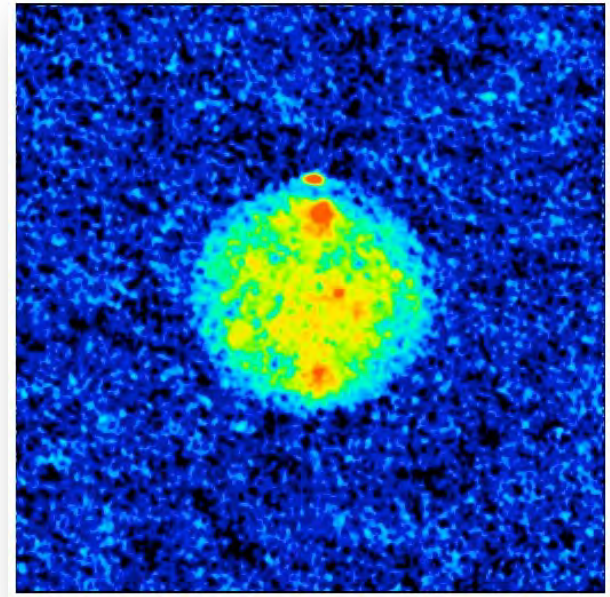
The surface of Mercury contains lava plains and is heavily cratered.

It appears to be very similar to our own moon but does have some important differences.



NASA Mariner 10

Recent evidence suggests that ice may exist in shaded craters at the poles.



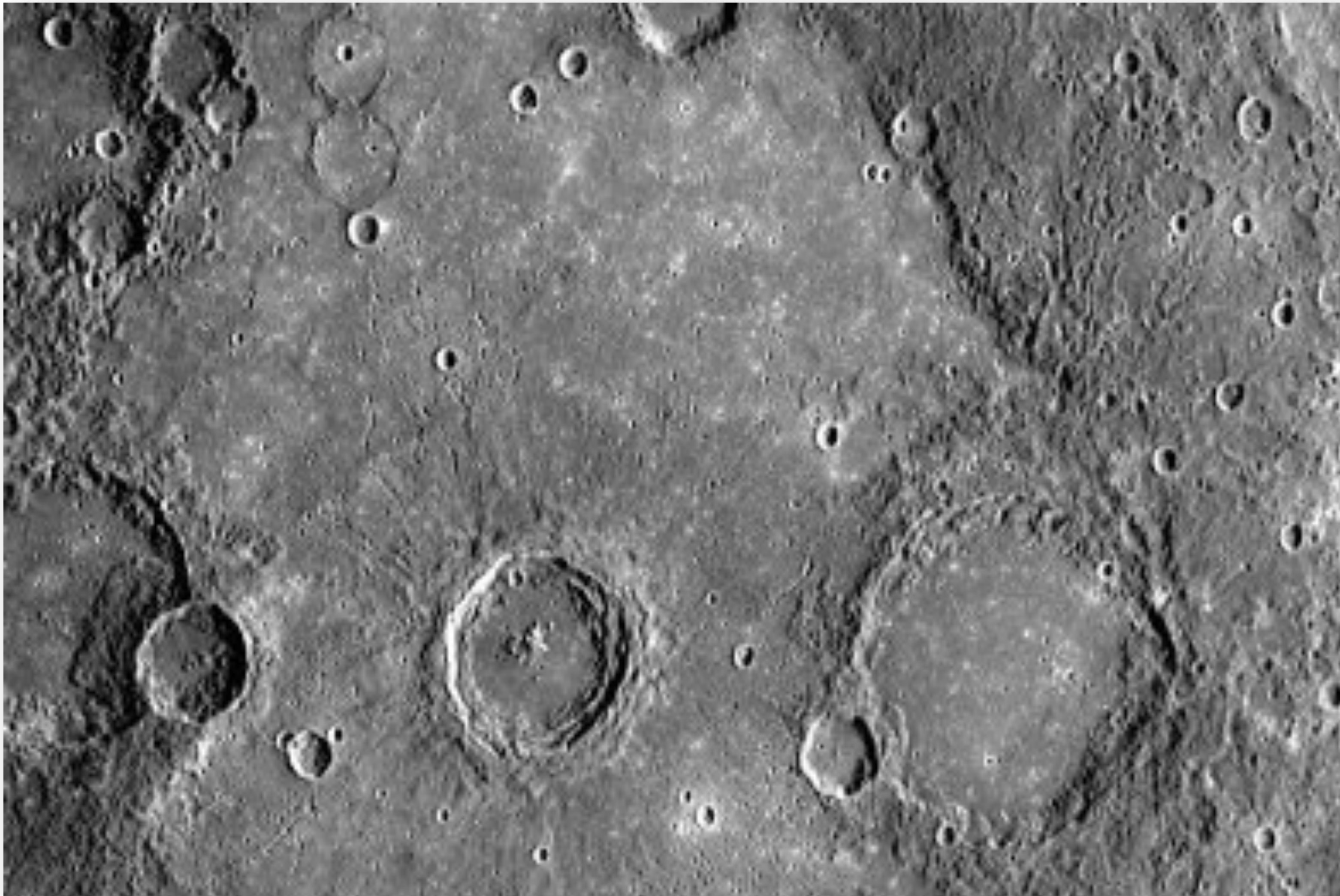
Very Large Array, National Radio Astronomy Observatory

Earth-based radar imaging of Mercury has revealed areas of high radar reflectivity near the north and south poles, which could be indicative of the presence of ice in these regions.

Presumably, the ice is located within permanently shadowed craters near the poles, where it may be cold enough for ice to exist over long periods of time.

There are two possible sources for ice on Mercury:

- meteorite/comet bombardment
- planetary outgassing



NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

The surface of Mercury contains numerous impact craters - indicating a ancient surface that may have not changed much since the formation of the planet. This image shows a smooth volcanic plain on Mercury indicating resurfacing processes.

Venus

Venus appears to be a planet that is similar to Earth - similar mass, density, size and location in the solar system.

The atmosphere of Venus is ~90 times more dense than Earth's and consists of 97% CO_2 (there is only a tiny amount of water).

NASA Galileo

The clouds that shroud the surface of Venus are composed predominantly of droplets of sulfuric acid.

The thick atmosphere composed of greenhouse gases gives Venus a runaway greenhouse effect and its surface temperature is ~482°C (hotter than Mercury!!).

mean distance from Sun	0.723 AU
radius	6051.8 km 0.949⊕
mass	4.49×10^{24} kg 0.81476⊕
density	5.25 g/cm^3
# moons	0

Because of the highly reflecting clouds, Venus is bright when it appears in our sky.

It is known as the evening or morning star and is 15 times brighter than the brightest star (Sirius).

NASA Galileo

We have been able to "view" the surface of Venus using radar.

Most of Venus (~65%) appears to be covered with rolling hills; about 24% is highlands and the rest are volcanic peaks.

Impact crater density dating of the surface of Venus indicates that it may be as young s 500-800 My old - comparable in age to much of the Earth's surface.

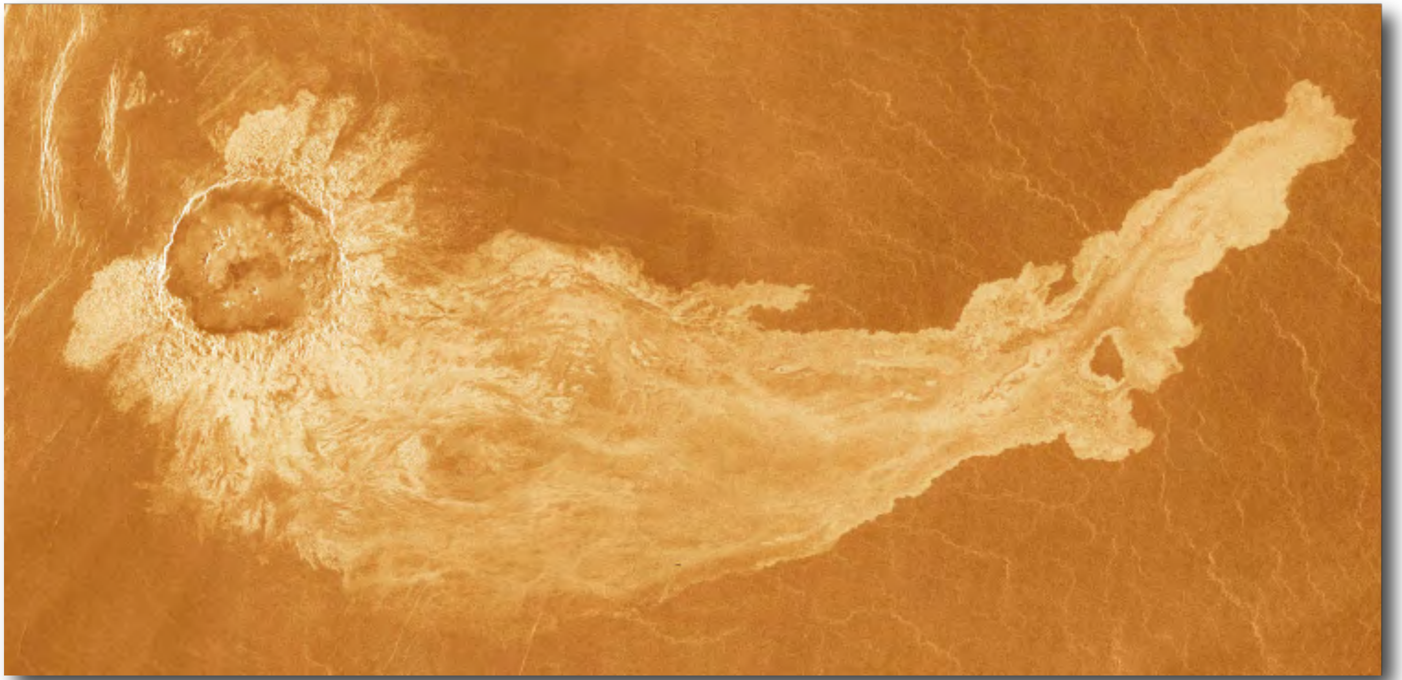
NASA

Impact crater with large lava flows — large flows are associated with impacts because of the high temp of the surface.

This is a Magellan radar image of Addams crater, a large impact crater. The radar bright region is a large lava flow associated with the 90 km crater and stretches over 600 km to the east.

Large flows are associated with impacts because of the high surface temperature of Venus.

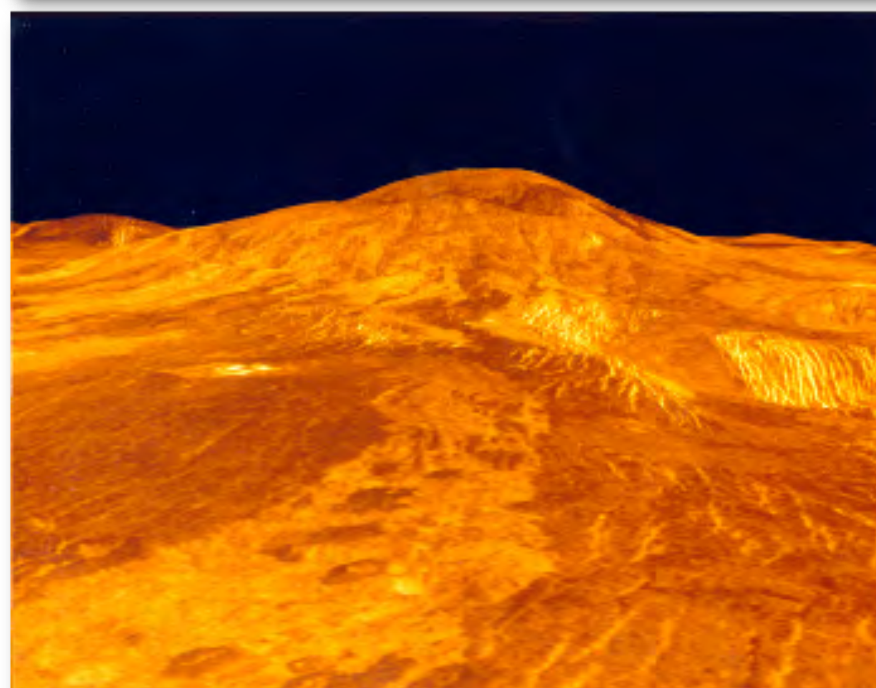
Impact features are rarer on Venus due to its very thick atmosphere - most incoming material burns up in the atmosphere.



NASA

These are radar images of a large shield volcano (Sapas Mons) on Venus.

There are thousands of volcanic structures on Venus. Most are small shield volcanoes but some are large like Sapas Mons (400 km across and 1.5 km high).



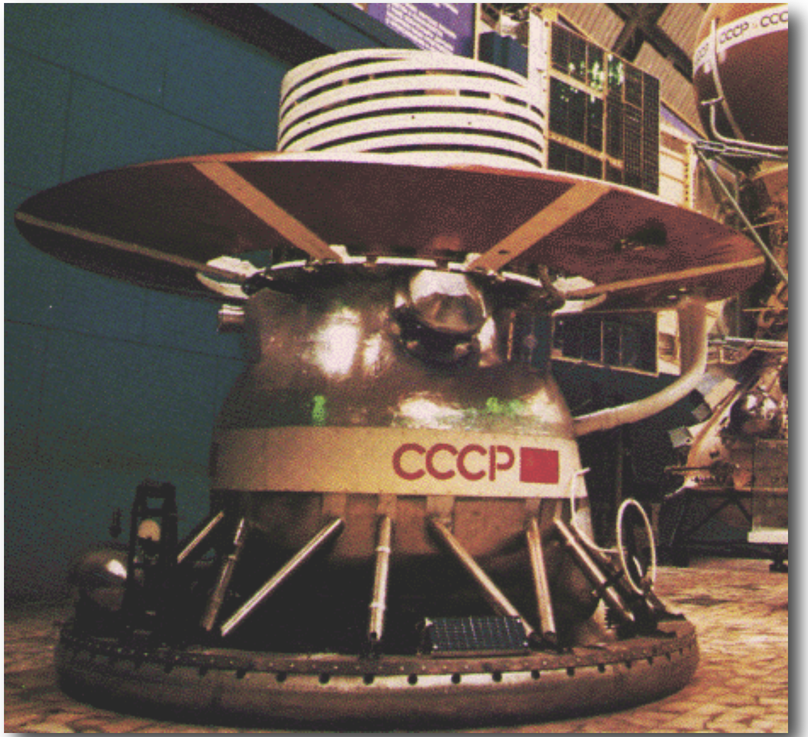
NASA

The Magellan radar image shows a bright wind streak associated with a small volcano. The northwest trending streak was probably formed by deposition of material in the wind shadow of the volcano. The volcano is about 5 km in diameter, and the wind streak is 35 km long and 10 km wide.

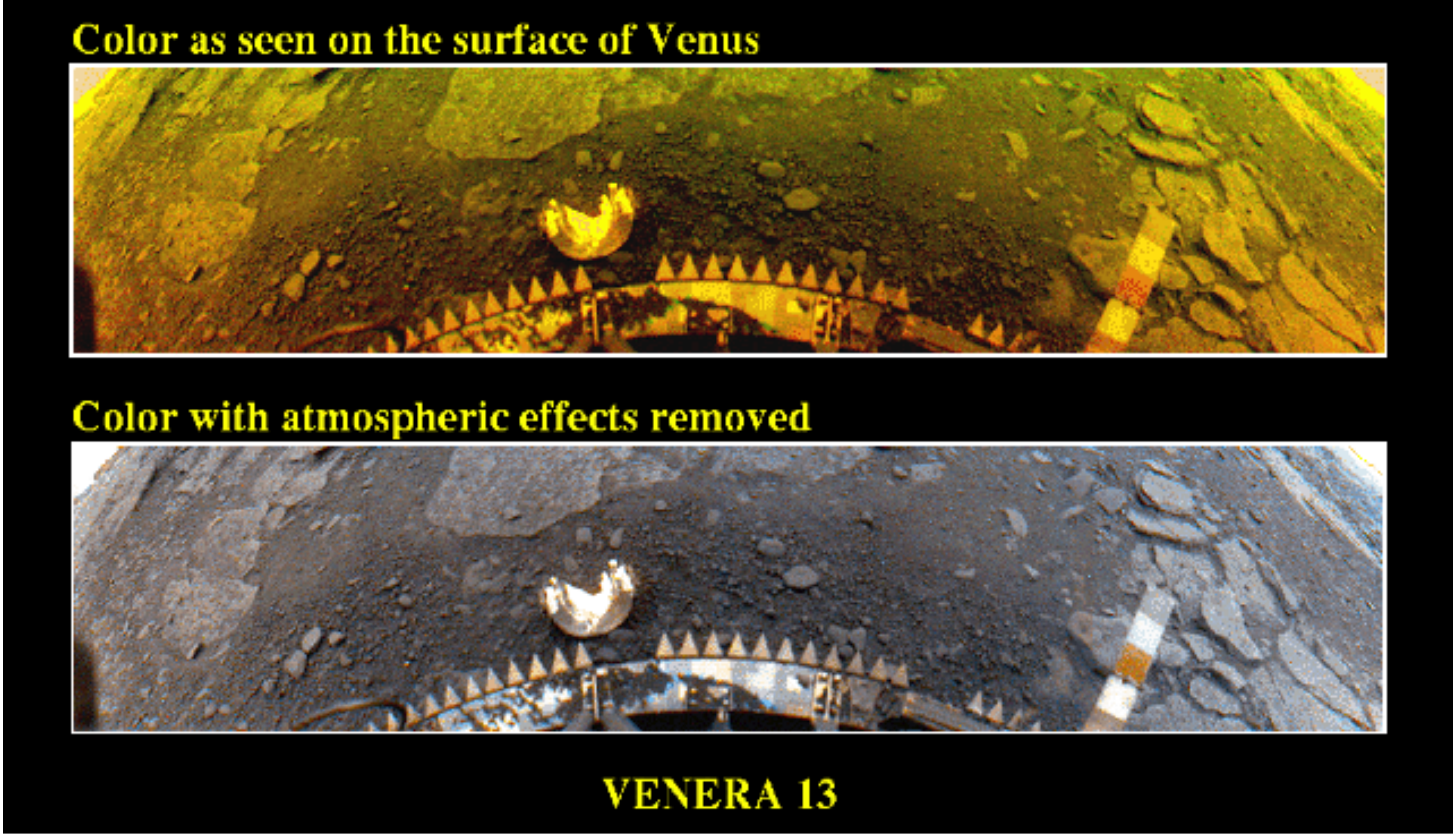
NASA Magellan

The Soviets sent several landers to Venus in the 1980's.

The photo to the right is the Venera 14 craft.



The lower image, from Venera 13, is a geometrically corrected view showing a ridge along the horizon



This Venera 13 image shows a soil surface with some evidence of wind processes. Venera 13 survived on the surface for 2 hours, 7 minutes. The surface composition appears similar to terrestrial basalt.

The top image shows that the surface is bathed in orange light from sunlight penetrating through the thick clouds.

Mars

Mars has captured the imagination of people for a very long time. Early telescopic observations of Mars indicated many Earth-like features on its surface.

NASA HST

mean distance from Sun	1.524 AU
radius	3397.2 km 0.533⊕
mass	6.421×10^{23} kg 0.107⊕
density	3.94 g/cm^3
# moons	2

The atmosphere of Mars is very similar to Venus in composition:

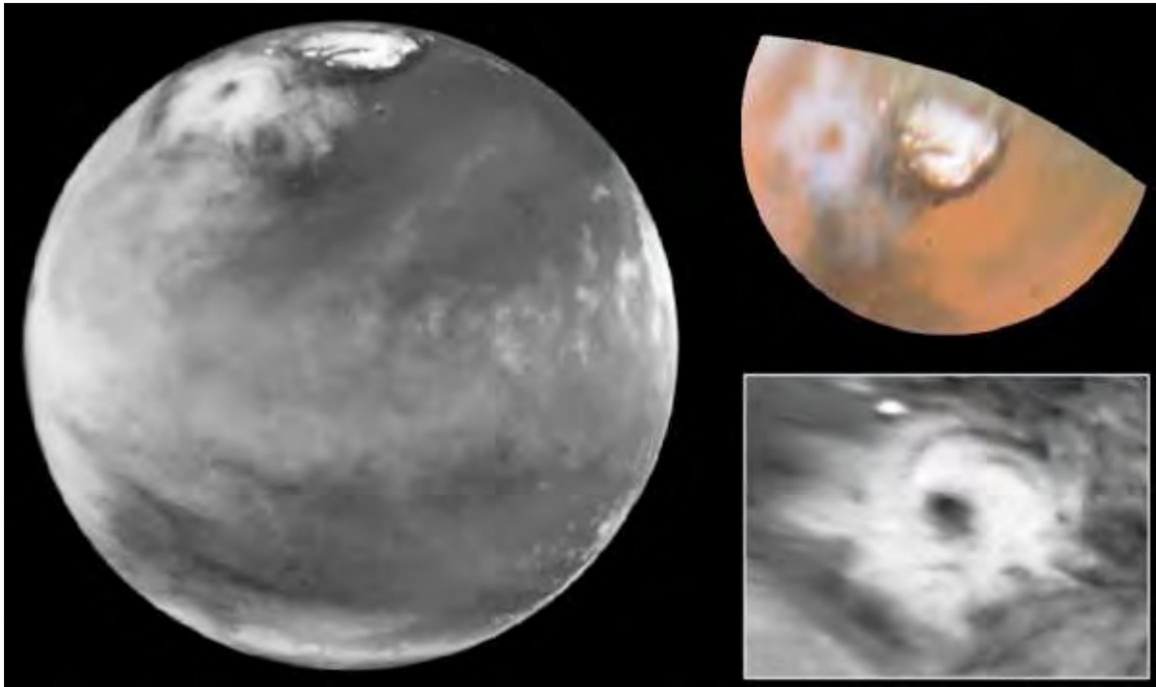
- 95% CO_2
- 3% N_2
- 2% Ar%

NASA Pathfinder

However it is only ~1% as dense as Earth's atmosphere (5-8 mbar).

We will see plenty of "geologic" evidence for surface water in the past. One conclusion is that the Martian atmosphere was much thicker in the past and that water flowed on the surface of Mars. However, it gradually lost its atmosphere to space.

Jim Bell (Cornell U.), Steve Lee (U. Colorado), Mike Wolff (SSI), and NASA



Mars contains many features that indicate that there may have been free liquid water at its surface.

Initially, observers speculated that Mars once had a water-rich atmosphere with rainfall and a hydrologic cycle similar to that on Earth.

However, today Mars only contains traces of water at its surface.

More recently, geologists have speculated that these features may be the result of the slow melting of subsurface water.

Either way, water is definitely present and *astrobiologists* are intrigued by the possibility of life on Mars (perhaps in the subsurface).

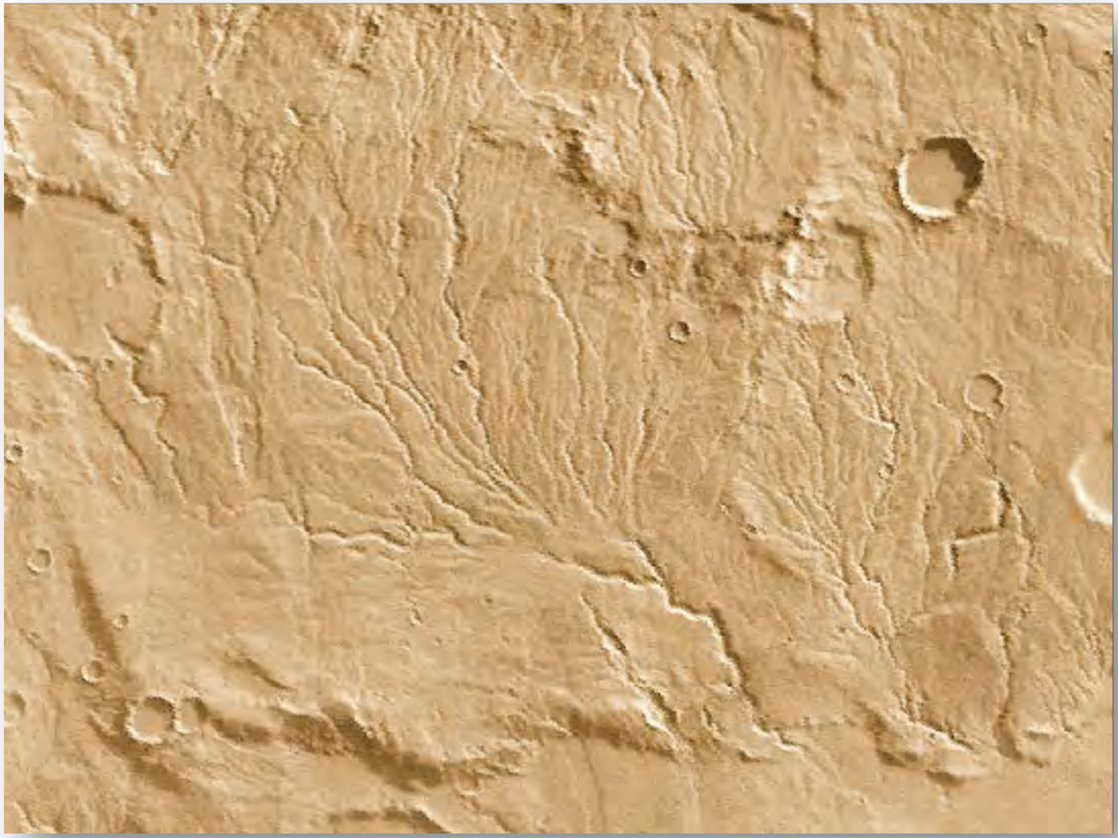


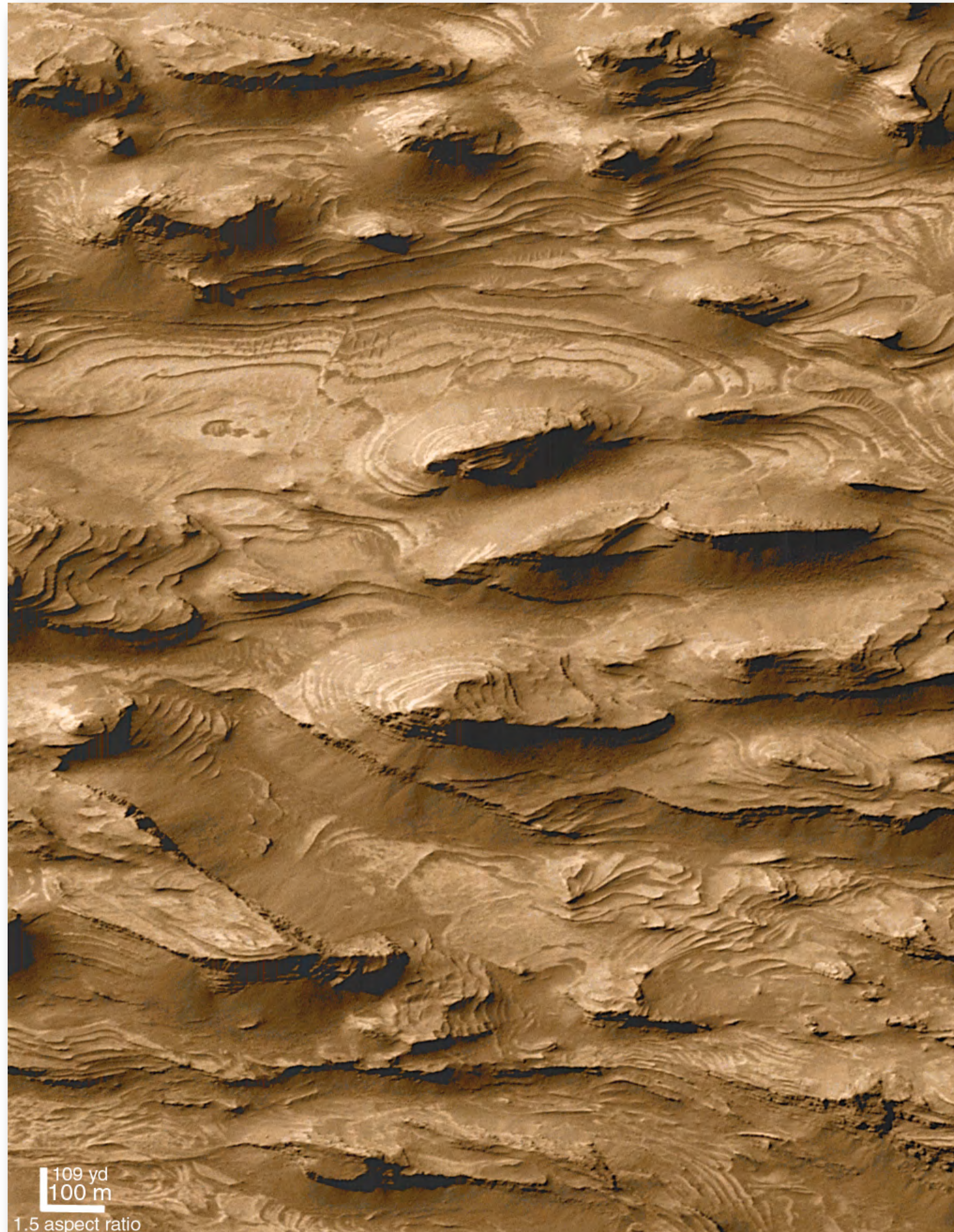
Image by Calvin J. Hamilton

This image is of Olympus Mons — the largest volcano in the solar system. It is the size of Ohio and is 23 km high (2.5 times higher than Mt. Everest).

It resembles the shield volcanoes of Earth such as the Hawaiian volcanoes. However, the extreme size is thought to result from the absence of plate movement on Mars — on Earth, plate movement results in the development of a line of smaller volcanoes.

NASA Viking 1

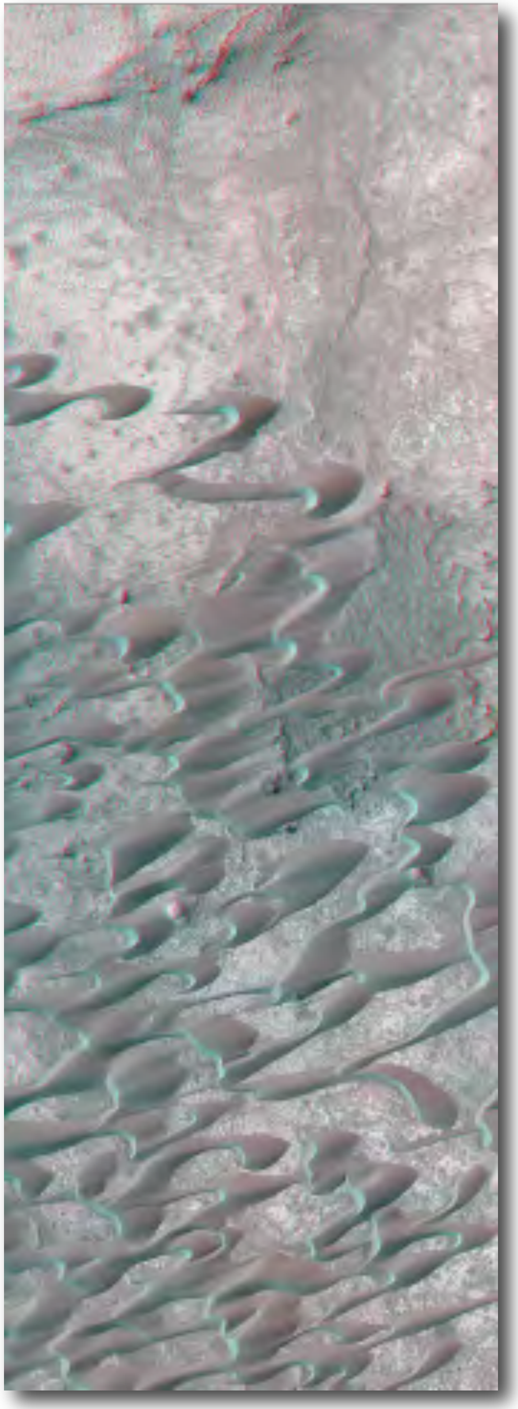
Image showing layered rock in the Valles Marineris. Speculations as to the origin of these interior layered materials ranged from volcanic ash deposits to sediments laid down in lakes The pattern suggests episodic deposition of materials. On Earth, this would represent sediment deposited in energetic, underwater environments.

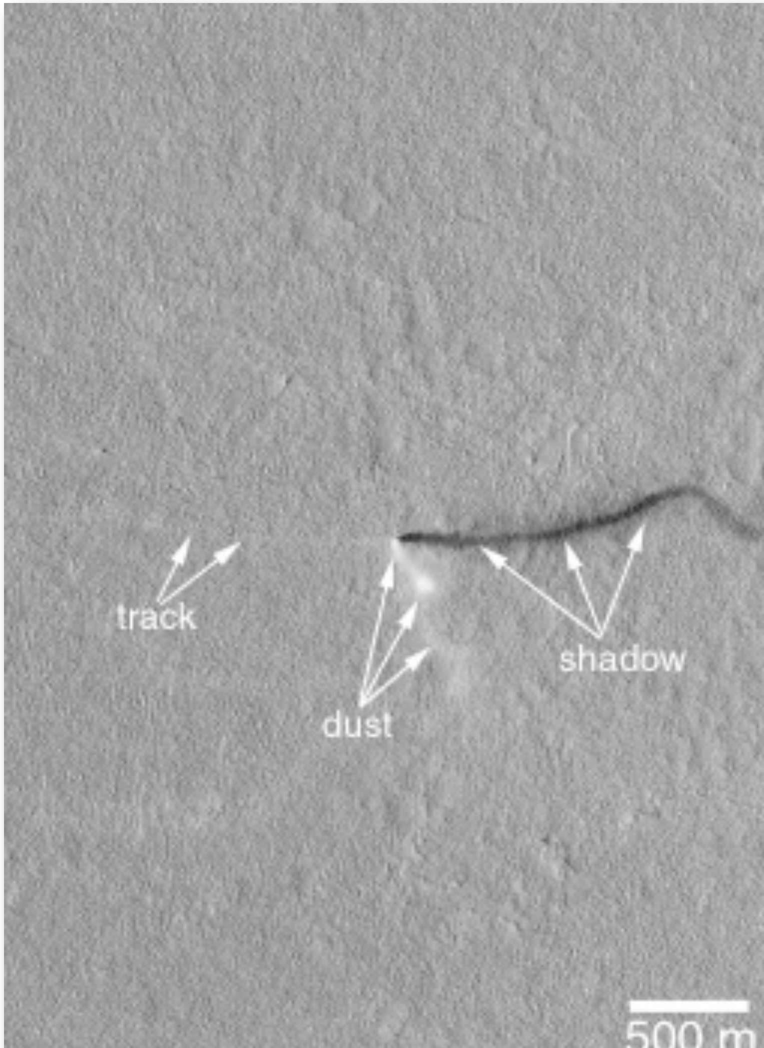


NASA Mars Global Surveyor

The image to the right shows a field of sand dunes located in Nili Patera, a volcanic depression in central Syrtis Major.

NASA Mars Odyssey





NASA/JPL/Malin Space Science Systems

The image is a dust devil. Dust devils are spinning, columnar vortices of wind that move across the landscape, pick up dust, and look somewhat like miniature tornadoes. Dust devils are a common occurrence in dry and desert landscapes on Earth as well as Mars.

A thin, light-toned track has been left by the dust devil as it moved across the landscape.

Dust devils most typically form when the ground heats up during the day, warming the air immediately above the surface. As the warmed air nearest the surface begins to rise, it spins. The spinning column begins to move across the surface and picks up loose dust (if any is present).

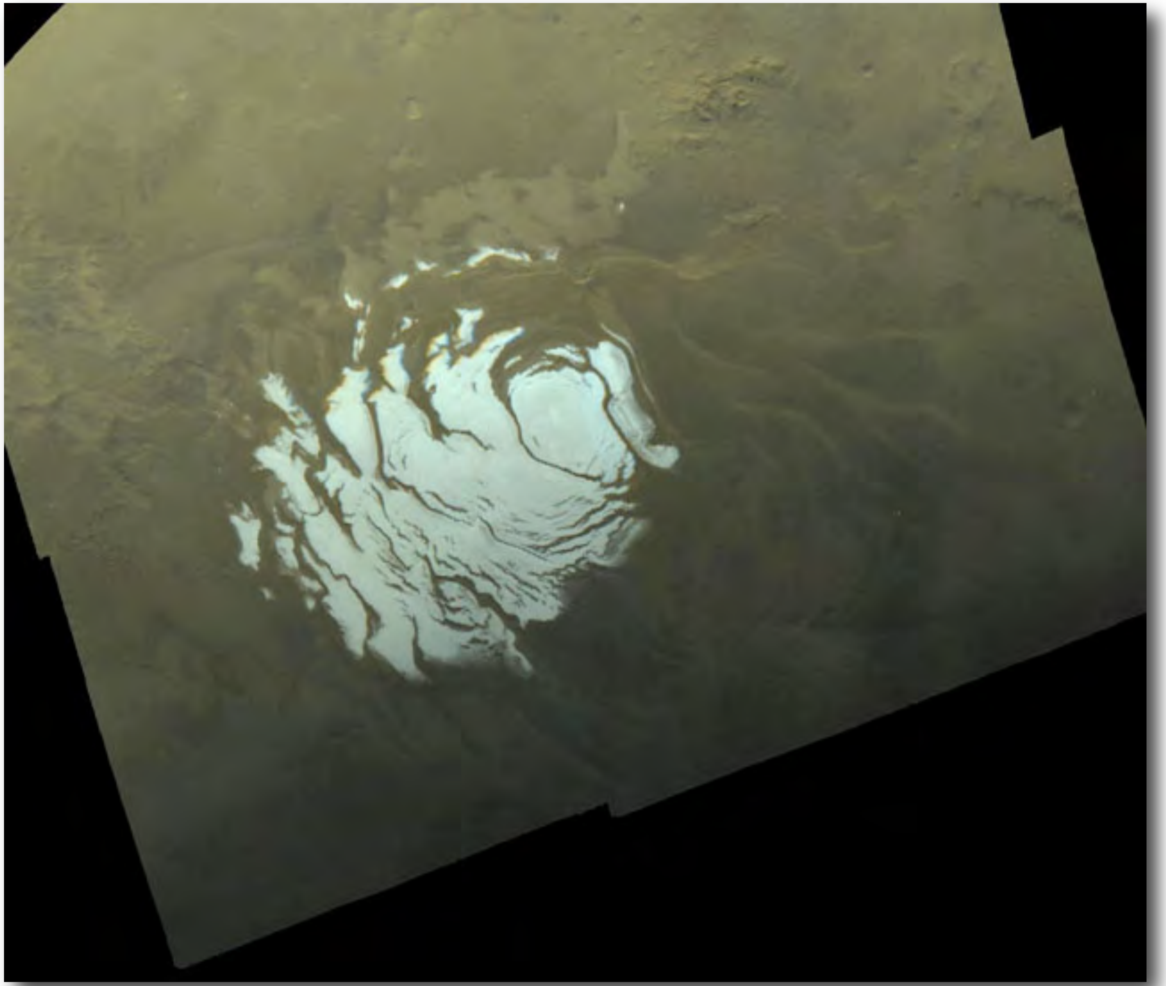
Another feature that Mars has in common with Earth is polar caps.

This is a mosaic of Viking 2 Orbiter images of the south pole of Mars.

The cap is about 400 km across in this image, taken during southern winter.

The polar ice caps of Mars are made of water ice, covered by a thin veneer of frozen carbon dioxide.

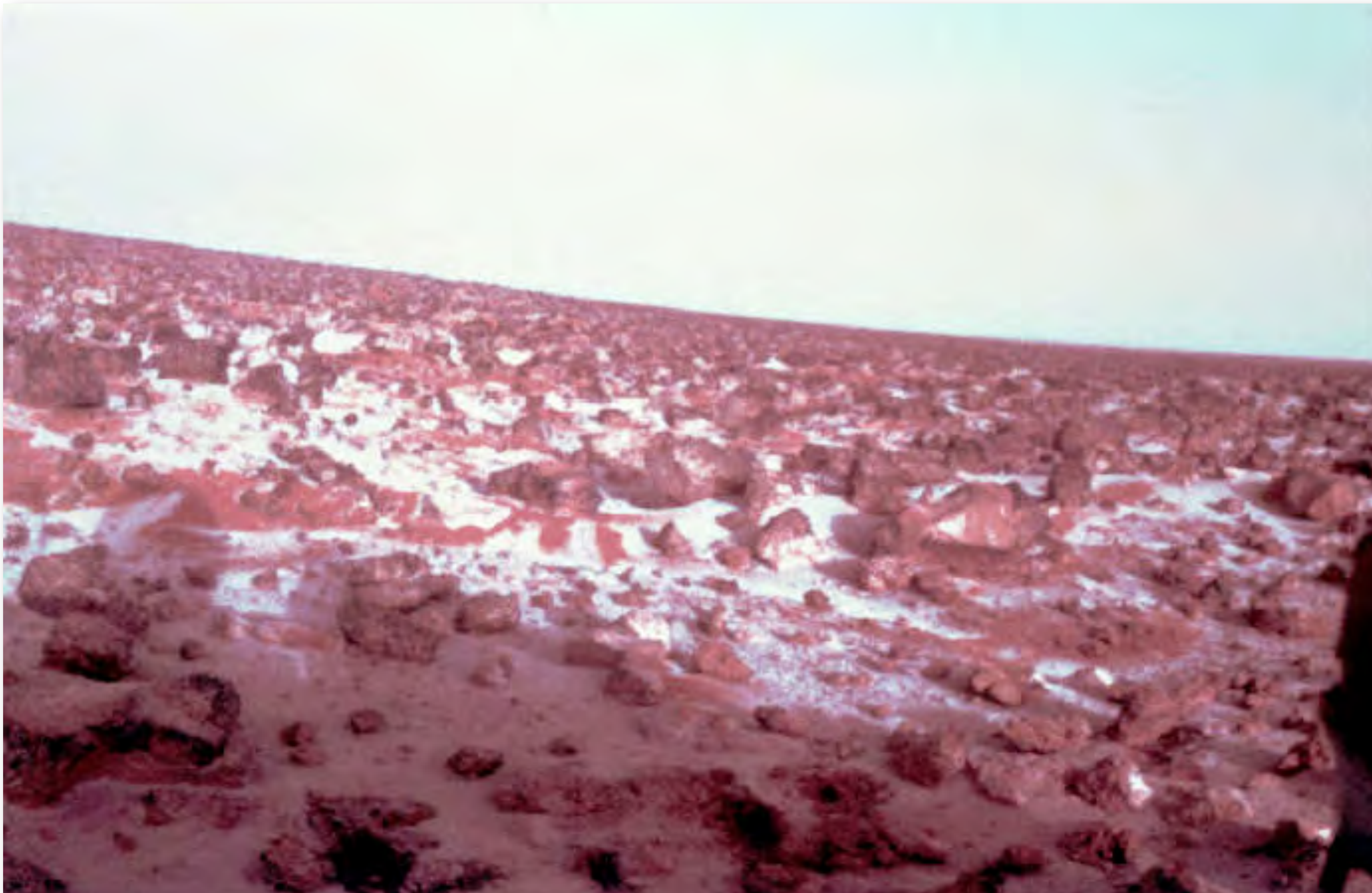
The polar caps wax and wane with the seasons.



NASA Viking 2

Mars

Image shows the development of frost in the morning on Mars.



Jupiter

Jupiter is the largest planet and accounts for 71% of the planetary mass in our solar system - that means more than twice as much mass as all the other planets combined.

Jupiter is so large that it exerts considerable (gravitational) influence over much of the solar system.

NASA Cassini

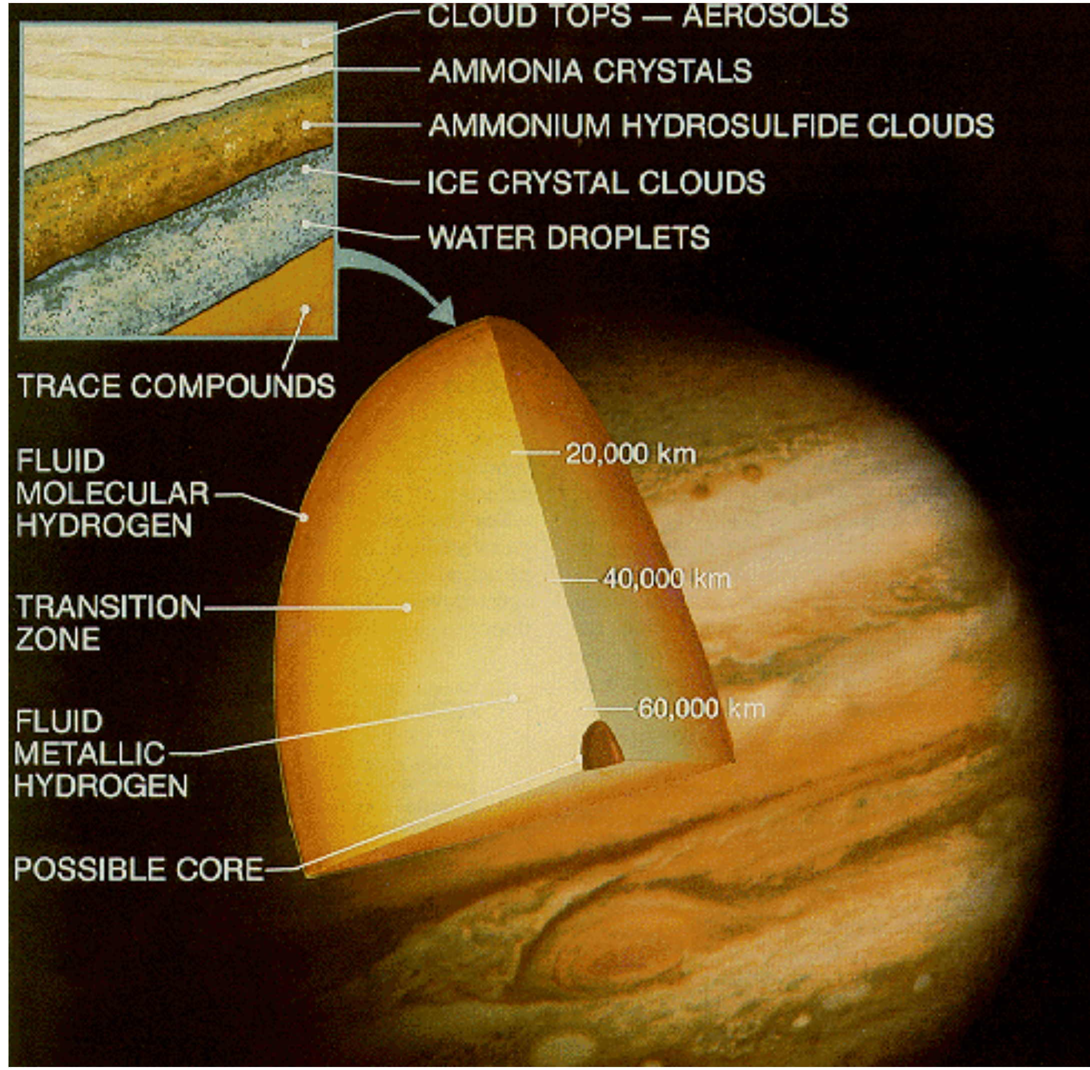
mean distance from Sun	5.203 AU
radius	71492 km 11.209⊕
mass	1.9×10^{27} kg 317.94⊕
density	1.33 g/cm^3
# moons	≥28

Jupiter is a gas giant planet with a composition similar to the Sun (mostly H_2 & He).

The outer part of the planet is composed of molecular hydrogen.

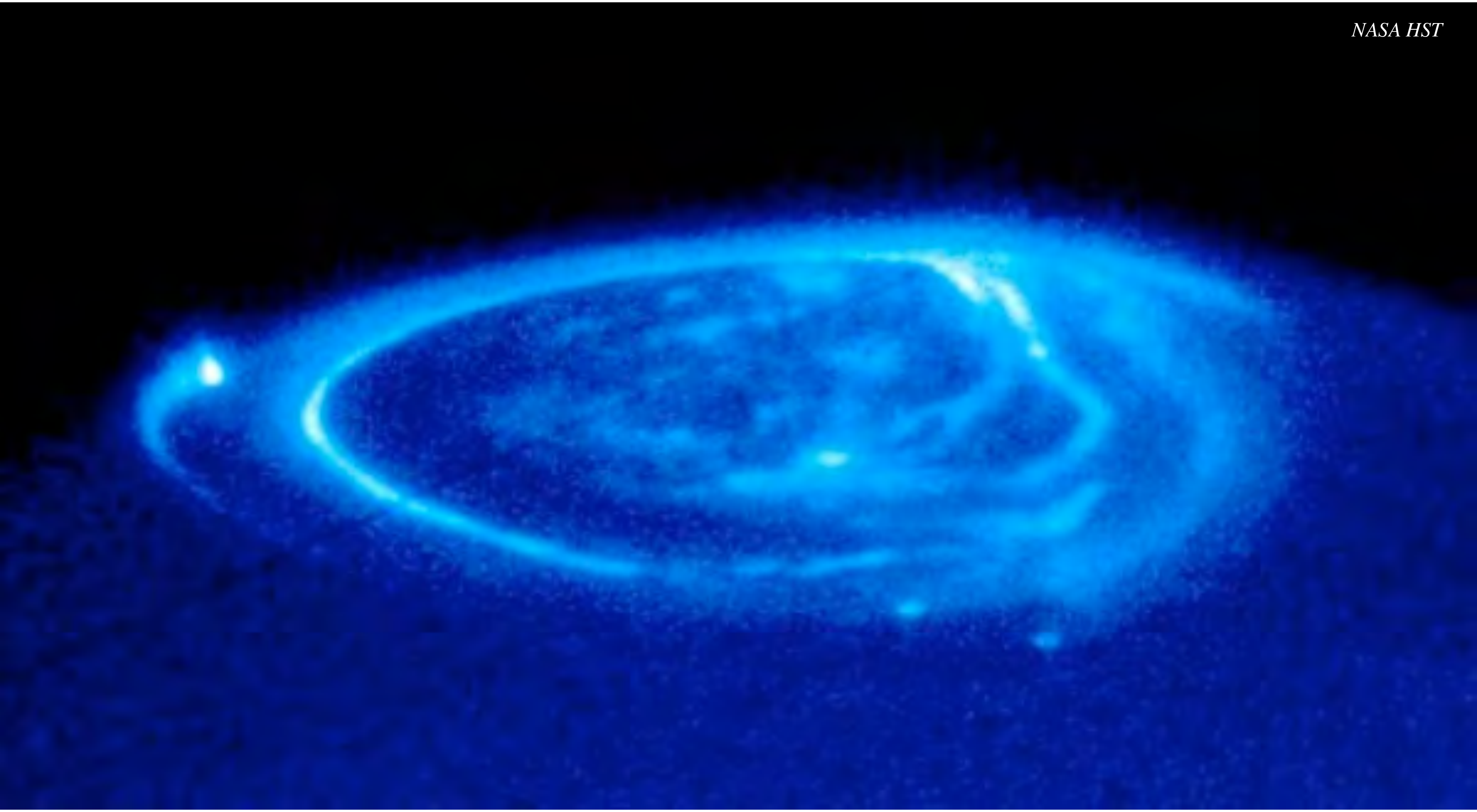
The core of the planet probably contains heavier elements such as Fe, Ni, and Si.

As you go into the interior, the pressure compresses the H_2 into liquid metallic hydrogen.



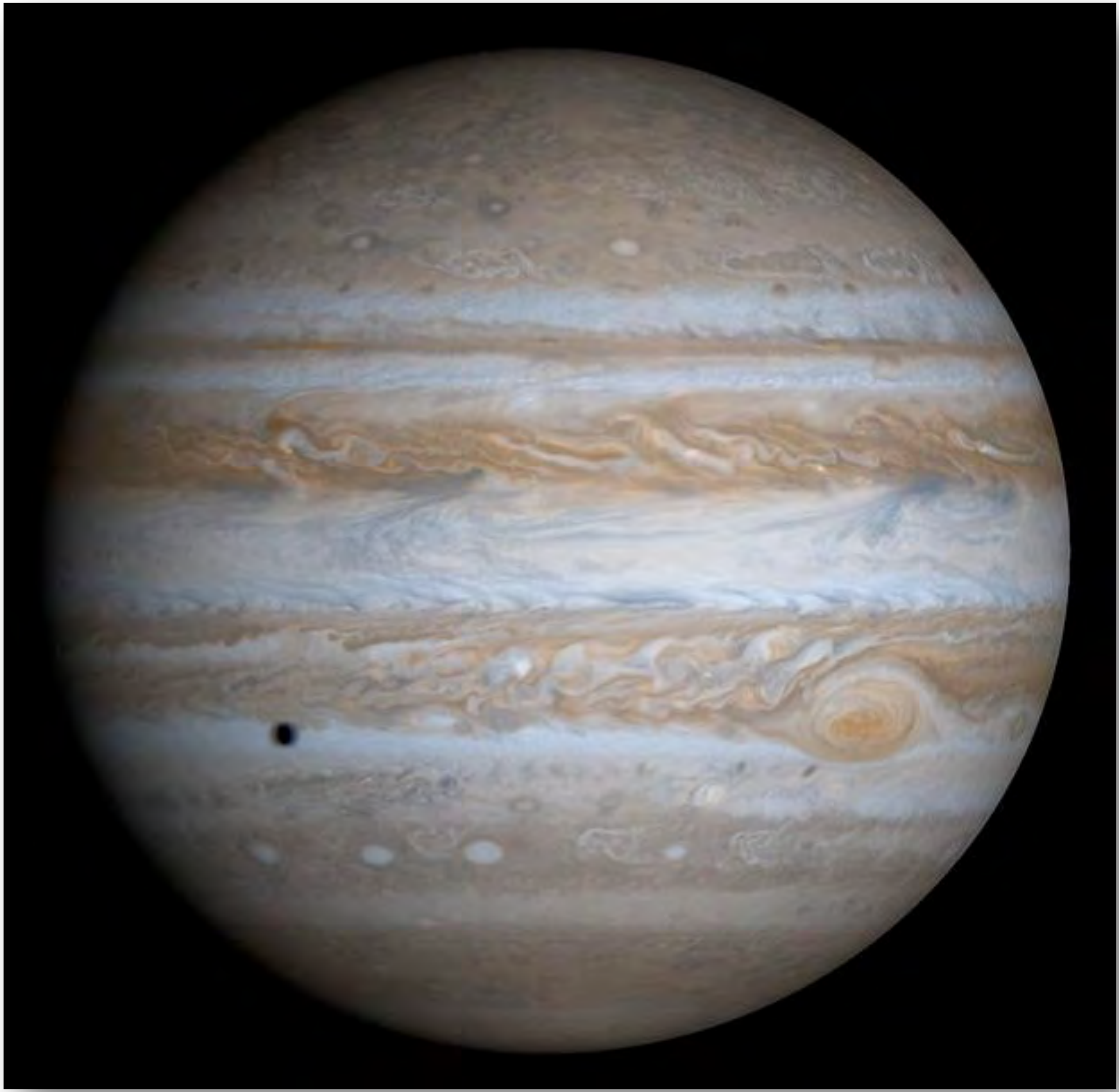
Metallic hydrogen is an excellent conductor and convection currents generate a magnetic field that is over 10 times stronger than Earth’s.

Like Earth, the magnetic field of Jupiter results in auroras.



The atmosphere of Jupiter is primarily molecular hydrogen (79% by mass), helium (19%), and trace amounts of water vapor, methane and ammonia.

The colored bands in the atmosphere run parallel to the equator and are due to layered clouds of water, methane, ammonia and other organic compounds.



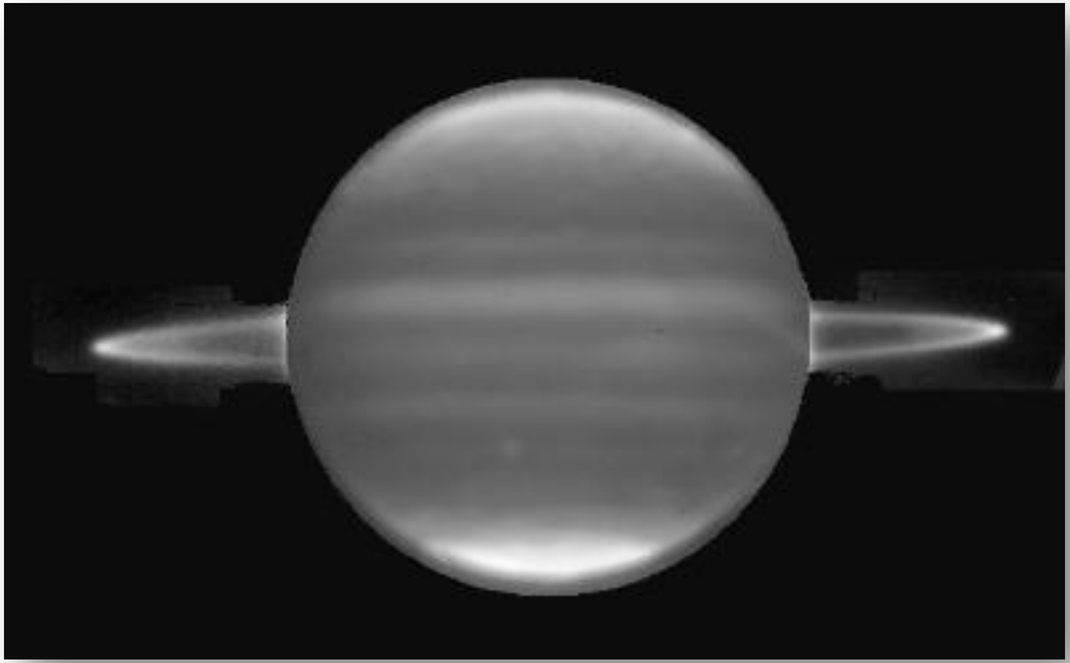
NASA Cassini

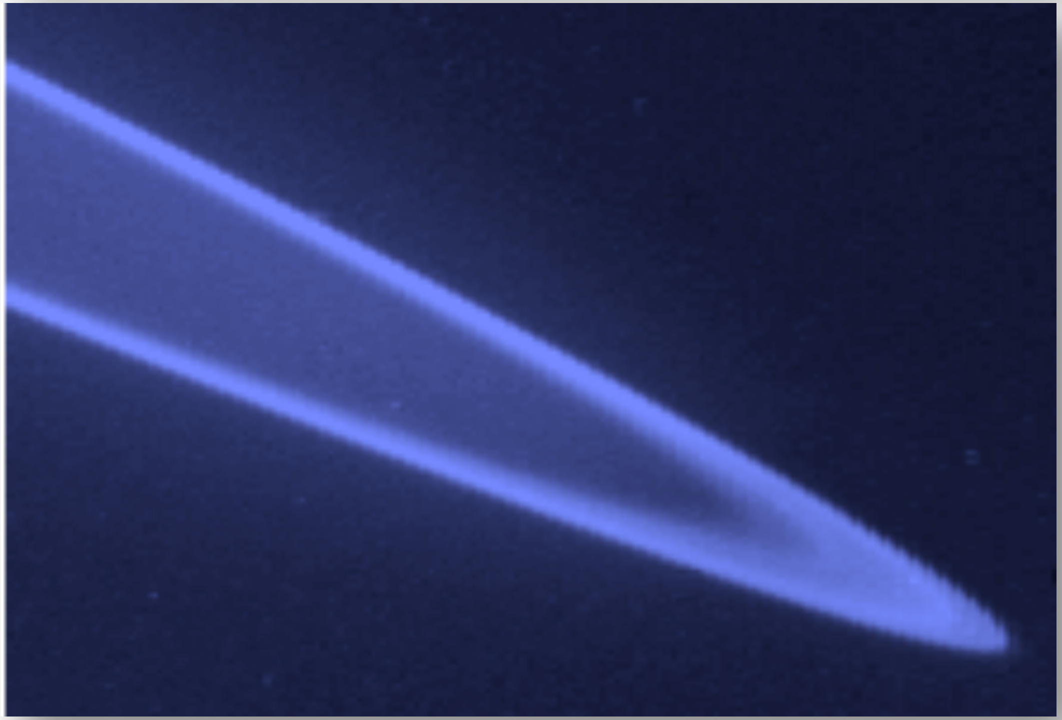
One of the most striking features of Jupiter is its *Great Red Spot* — which has been observed for nearly 400 years.

The Great Red Spot is an anti-cyclonic (high pressure) storm; it is enormous (three Earths would fit within its boundaries) with a rotation period of about 6 days.

NASA Voyager 1

Like the other Jovian planets, Jupiter has a ring system. However, it is so faint that it was not discovered from Earth but was first photographed by Voyager I. The particles are produced by micrometeorites striking small moons near the outer edge of the ring.



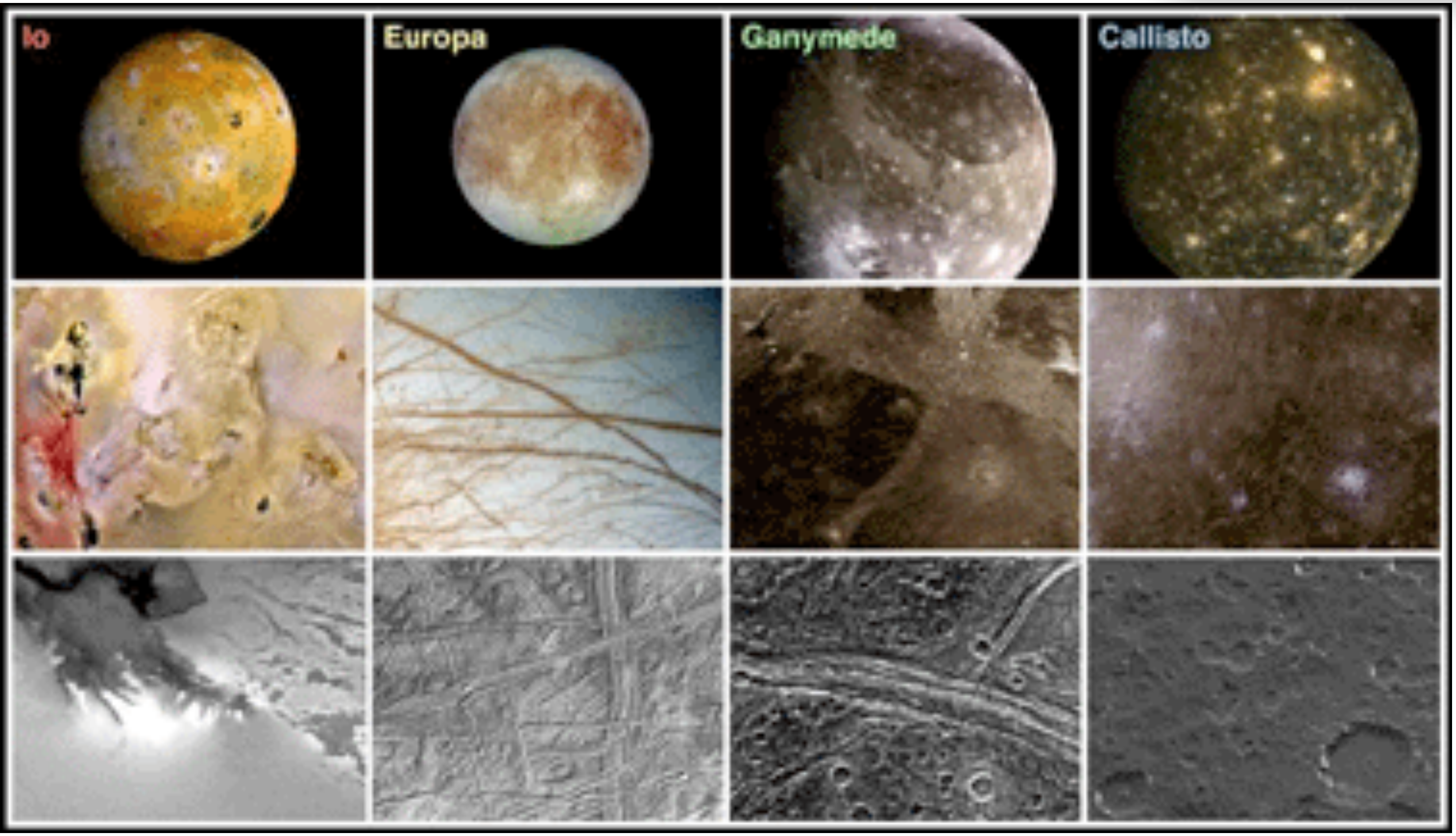


NASA Voyager 1

Jupiter’s Moons

Jupiter has a large number of moons, most of which are probably captured asteroids.

Galileo discovered the four largest known as the Galilean moons: Io, Europa, Callisto and Ganymede.



These moons are large enough to have distinct “geologic” characters.

NASA JPL

Saturn

Saturn is the second largest of the planets. Its composition is like the Sun and Jupiter — primarily of H_2 & He.

The photo shows Saturn with its rings and 2 of its over 2 dozen moons.

NASA HST

mean distance from Sun	9.539 AU
radius	60,268 km 9.449⊕
mass	5.688×10^{26} kg 95.181⊕
density	0.69 g/cm^3
# moons	≥30

Saturn's rings are its most striking feature — they are easily visible from Earth.

The rings are composed of billions of icy particles ranging from dust to boulders. The rings are composed of hundreds of ringlets.

NASA HST

The rings are thought to consist of material from the collision of comets with the moons of Saturn.

The gaps in the rings are believed to be due to small satellites that clear particles in their orbital paths and gravitational resonance with satellites.

NASA Cassini

Uranus

Uranus was discovered by accident during a survey of stars in 1781.

Uranus is only 1/3 the diameter of Jupiter. It appears as a featureless blue-green disk

NASA Voyager 2

mean distance from Sun	19.194 AU
radius	25,559 km 4.007⊕
mass	8.686×10^{25} kg 14.535⊕
density	1.29 g/cm^3
# moons	≥21

The atmosphere is composed of the same proportions of H_2 & He found in the Sun and other Jovian planets.

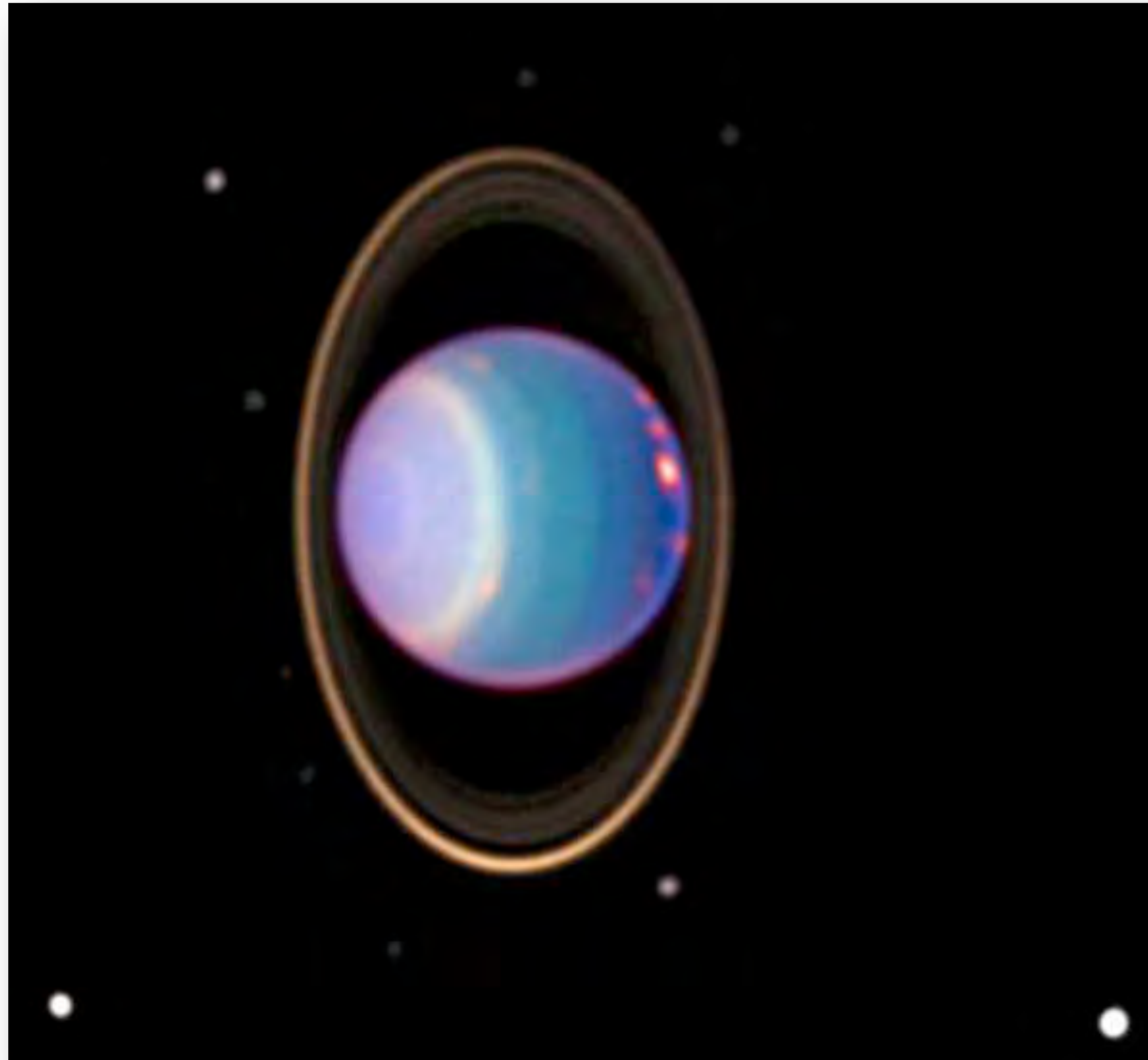
The bluish color is due to CH_4 absorbing red photons.

The most striking thing about Uranus is that it is tilted almost 90° to the ecliptic (lies on its side).

For part of a year on Uranus the N. pole points to the Sun and the S. pole remains in darkness.

This reverses as the planet revolves around the Sun.

Each season lasts over 20 Earth years.



NASA HST

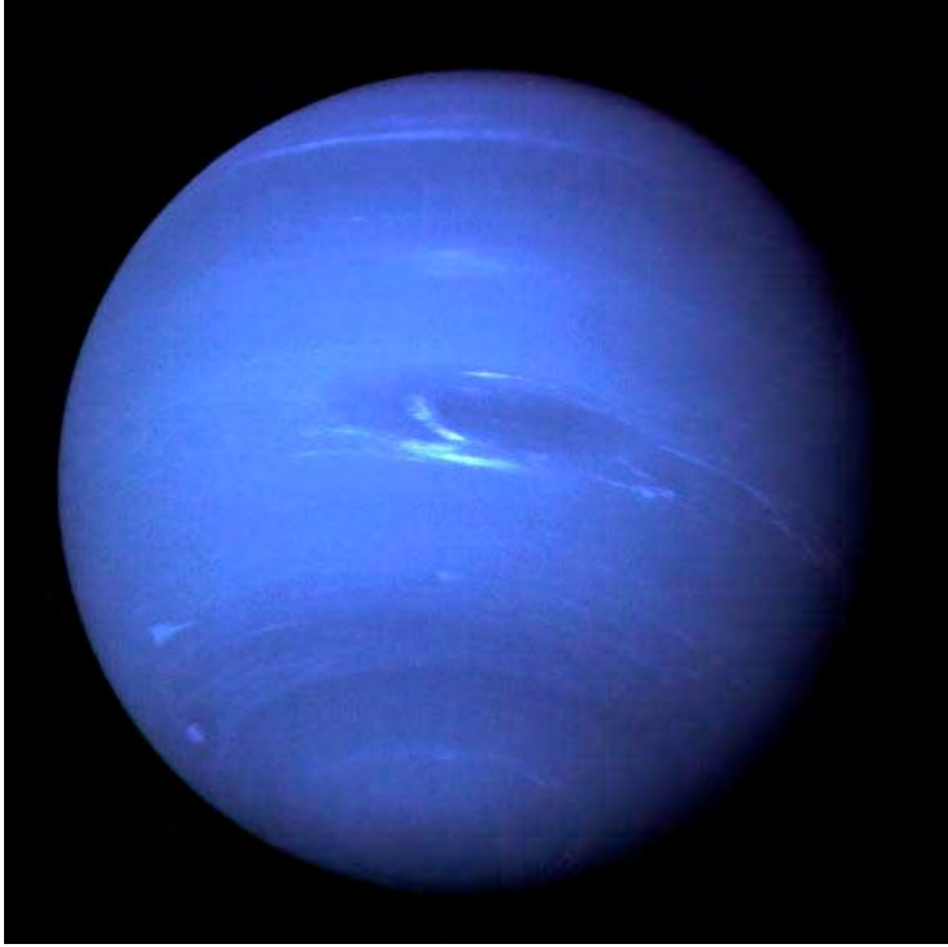
The figure shows the rings and some of the 15 moons of Uranus which are also inclined like the planet suggesting that it was subjected to a huge impact during formation.

Neptune

Neptune is the twin of Uranus — the composition of the atmospheres are nearly identical and Neptune is only 4% smaller than Uranus.

Neptune is noticeably bluer than Uranus because of it slighter higher methane content.

mean distance from Sun	30.0611 AU
radius	24,746 km 3.8799⊕
mass	1.024×10^{26} kg 17.135⊕
density	1.64 g/cm^3
# moons	≥8



NASA Voyager 2

Neptune was discovered because its gravitational force perturbed the orbit of Uranus - indicating another planet beyond.

Pluto

Pluto is a dwarf planet and represents objects in the Kuiper Belt. The surface temp is ~36K.

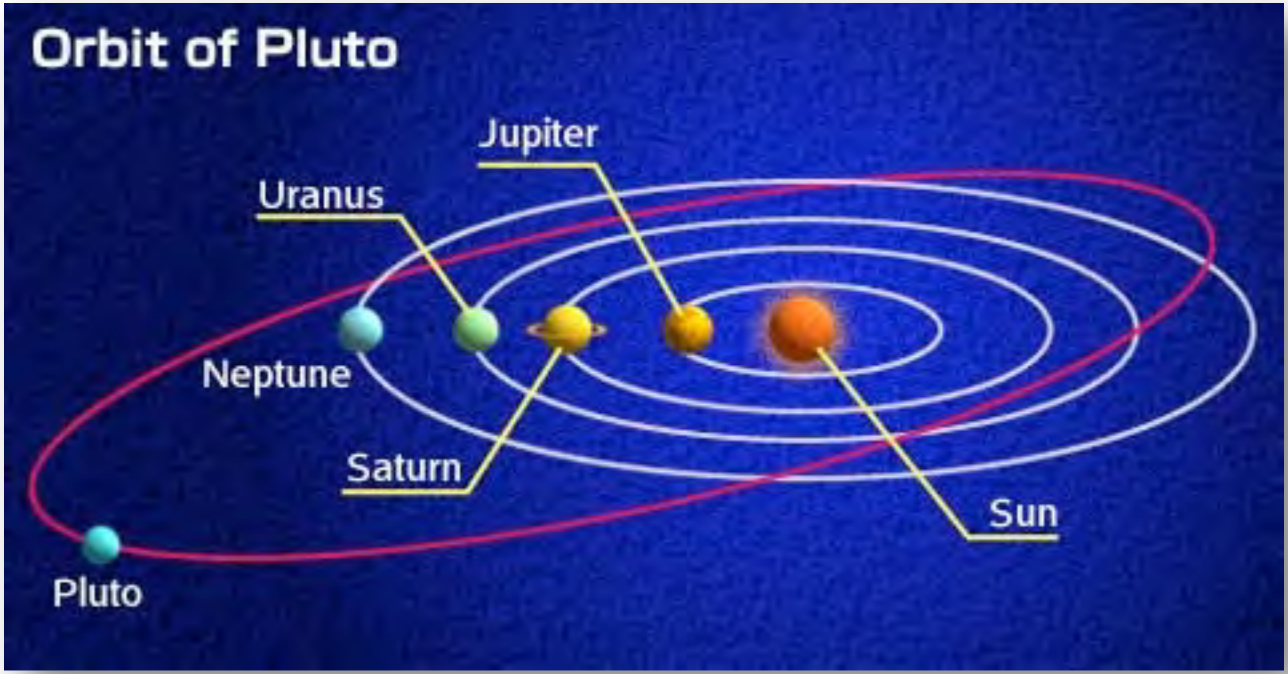
It is so distant and small that very little is known about it.

mean distance from Sun	39.5294 AU
radius	1,137 km 0.1783⊕
mass	1.27×10^{22} kg 0.00212⊕
density	2.05 g/cm^3
# moons	1

The top image shows Pluto and its moon Charon. The lower photo represents the best resolved images of the surface of Pluto.

It is not like the outer gas giant planets.

Most planets' orbits are nearly circular, but the orbit of Pluto is highly elliptical. In fact, from Jan. 21, 1979 until March 14, 1999, it was closer to the Sun than Neptune.



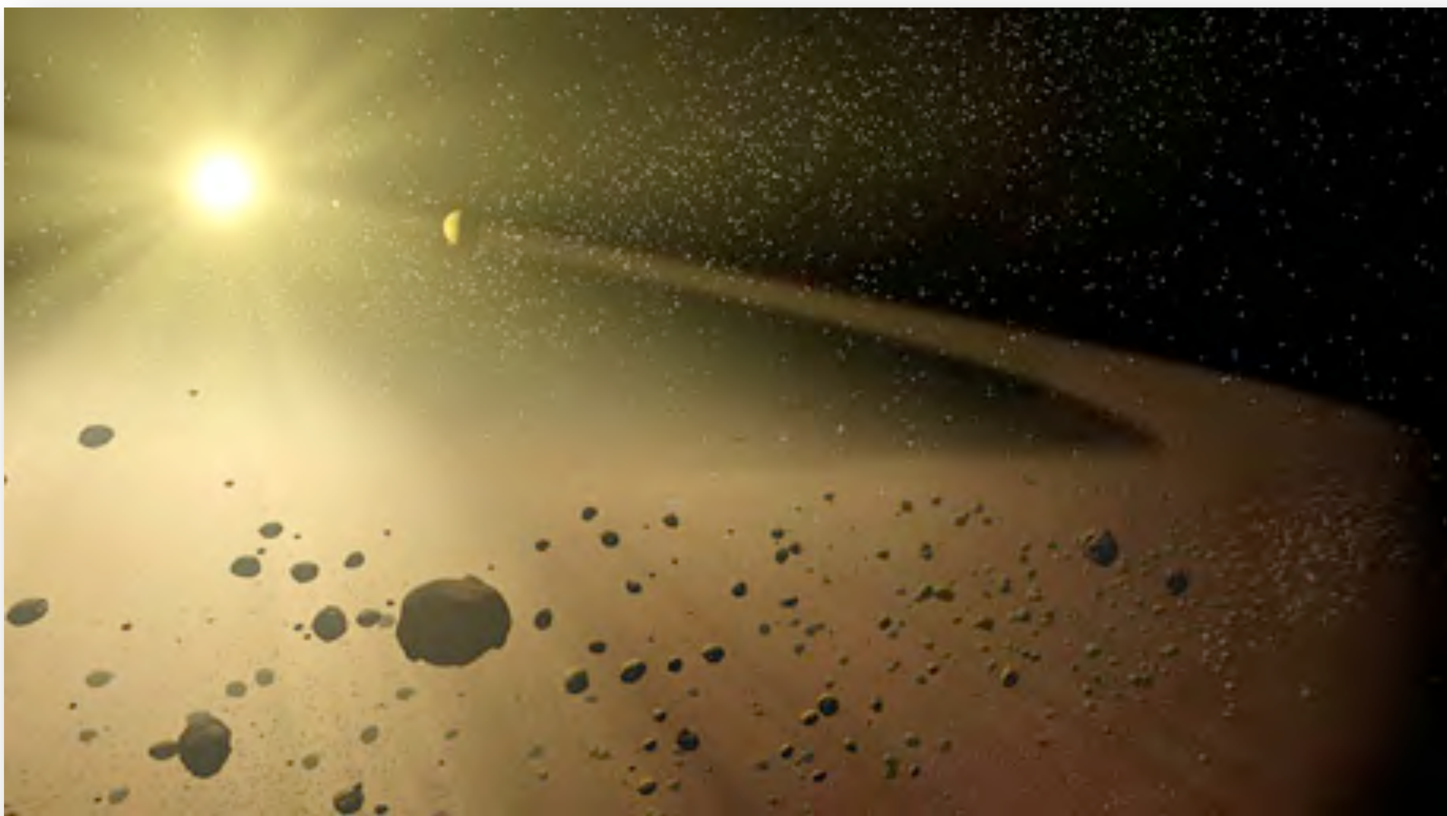
Pluto has one moon, Charon, that is nearly half its size. This leads some to consider Pluto-Charon as a double planet system. The figure on the right shows the relative sizes of Pluto, Charon, and the Earth.

Pluto is so distant from the Sun that the Sun only appears as a bright star.

IV. Origin of the Solar System

The Big Bang occurred ~13.77 billion years ago. Our galaxy formed 10-12 billion years.

Our solar system is relatively young and formed only ~4.6 billion years ago. That means that our solar system has formed in only the last ~38% of our galaxy's history.



PBS

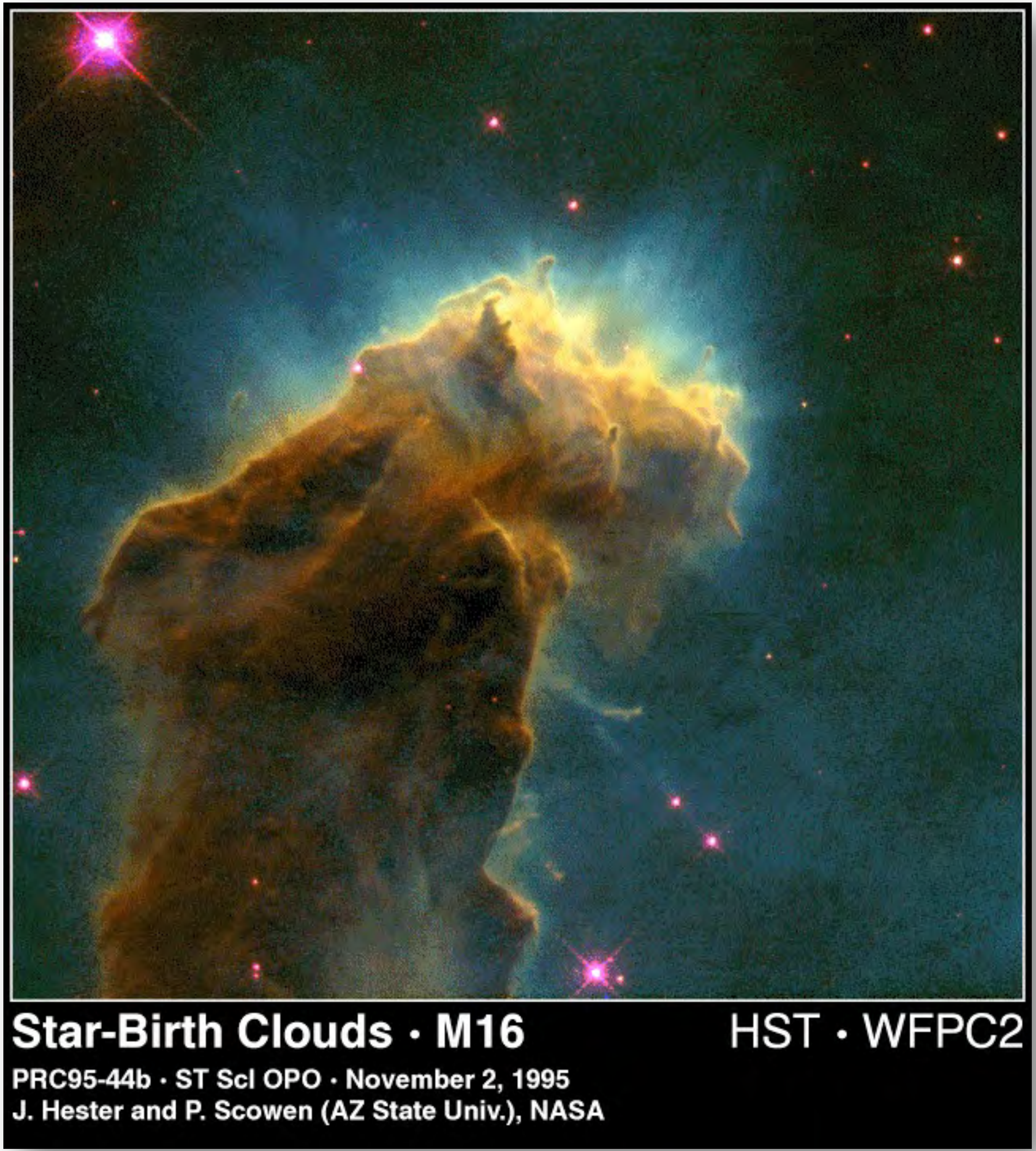
Evidence that Stars are Still Forming Today

1. The relative youth of our Sun (solar system) is one line of evidence that all stars did not form in the beginning and are continuing to form.
2. Modeling of stellar evolution: — our Sun may last for ~10 Gy. Stars of ten solar masses last only ~0.01 Gy. Those that are several tens of solar masses may only survive for a few million years before exploding in a supernova. Even though these stars are short-lived, many of these massive stars exist and supernovae have been recorded throughout history.
3. New technologies such as the Hubble Space Telescope have enabled us to observe stars and planetary systems forming from nebulae.

Interstellar Material

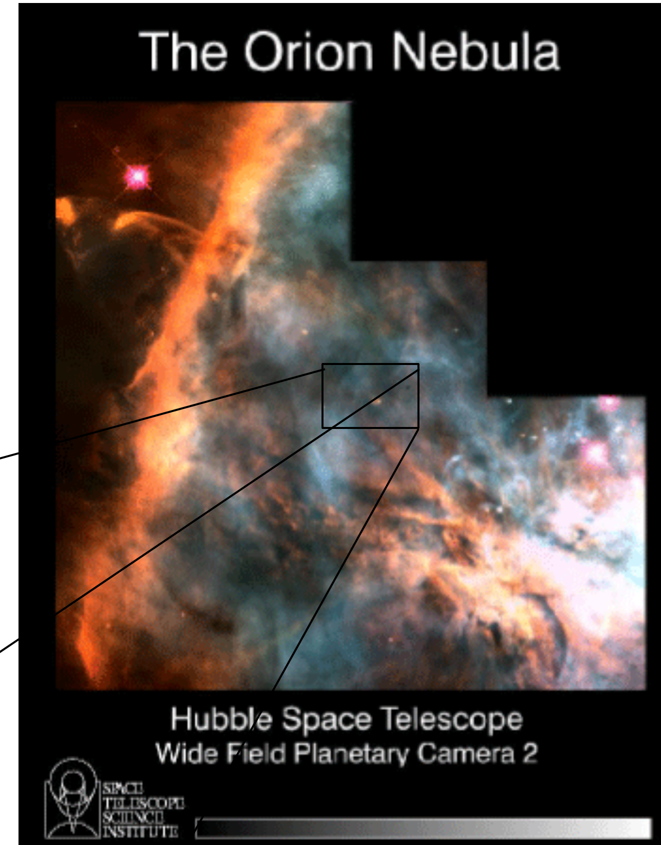
The most accepted theory of the origin of stars and planetary systems is the collapse of interstellar gas and dust.

To understand this process, we should understand the nature of the *building materials*.



Direct Observations of Newly Formed Stars: Proplyds

The HST has revealed small clots of dense gas believed to be cocoon nebulae just forming. These are known as *proplyds* (PROtoPLanetarY DiskS).



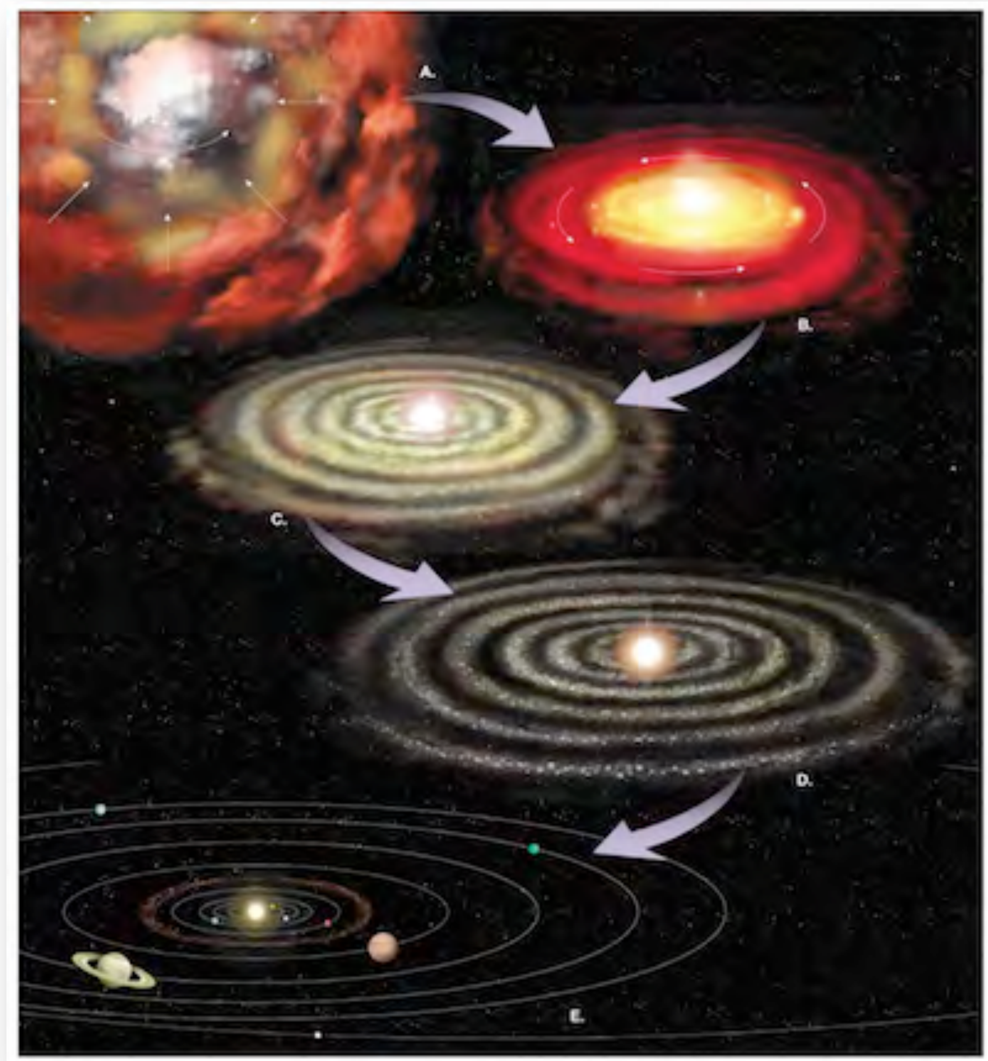
They typically range around several hundred AU which matches the size of our own solar system.

One study in the Orion nebula identified 56 stars with *proplyd* structures out of 110 stars in the field.

Our understanding of the solar nebular theory is that planets form as a by-product of star formation.

1. If the nebula is compressed (overcoming the gas pressure), then gravity may take over and the nebula will collapse inward.

2. As nebular particles come closer together, the gravitational attraction increases (remember the law of gravitation). The increased attraction and collapse results in an increase in temperature. As the cloud collapses, it begins to slowly rotate and flatten into a disk.

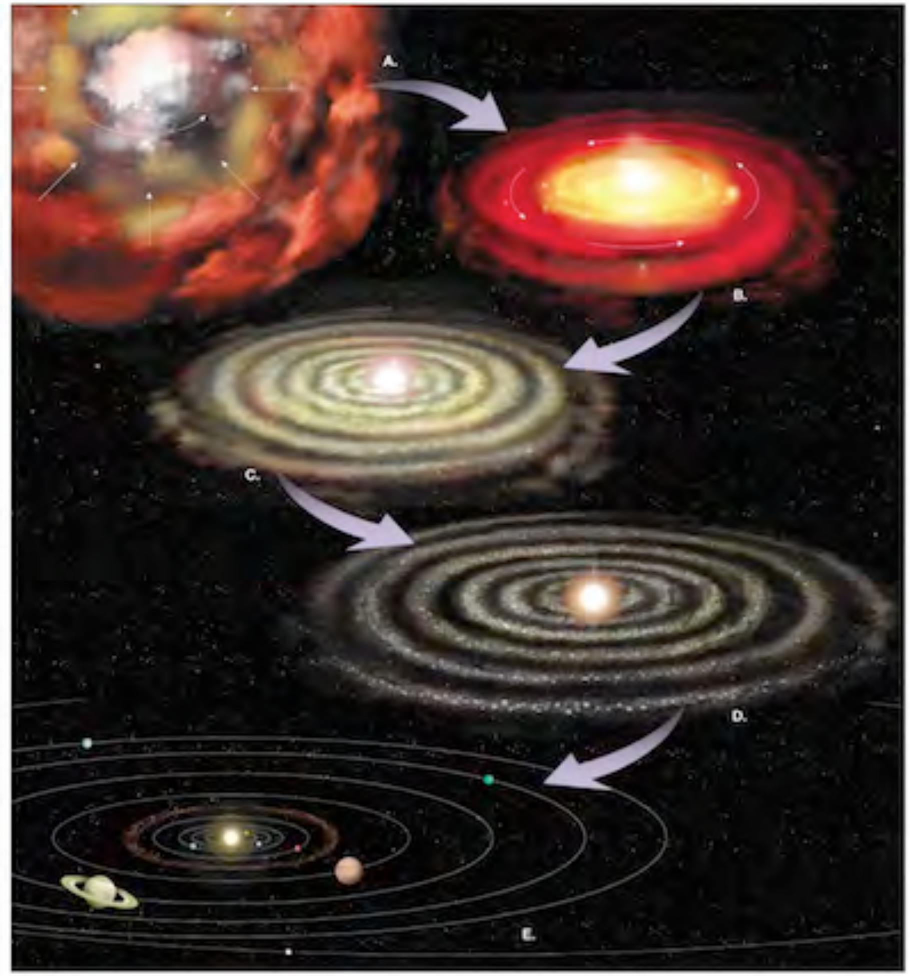


AstronomyOnline

3. As the cloud continues to collapse, dust particles stick together to form larger particles known as planetesimals. These planetesimals quickly grow to sizes up to kilometers across as they sweep out and accrete matter in their orbital path.

4. The largest planetesimals in each orbit would combine and accrete material to form protoplanets.

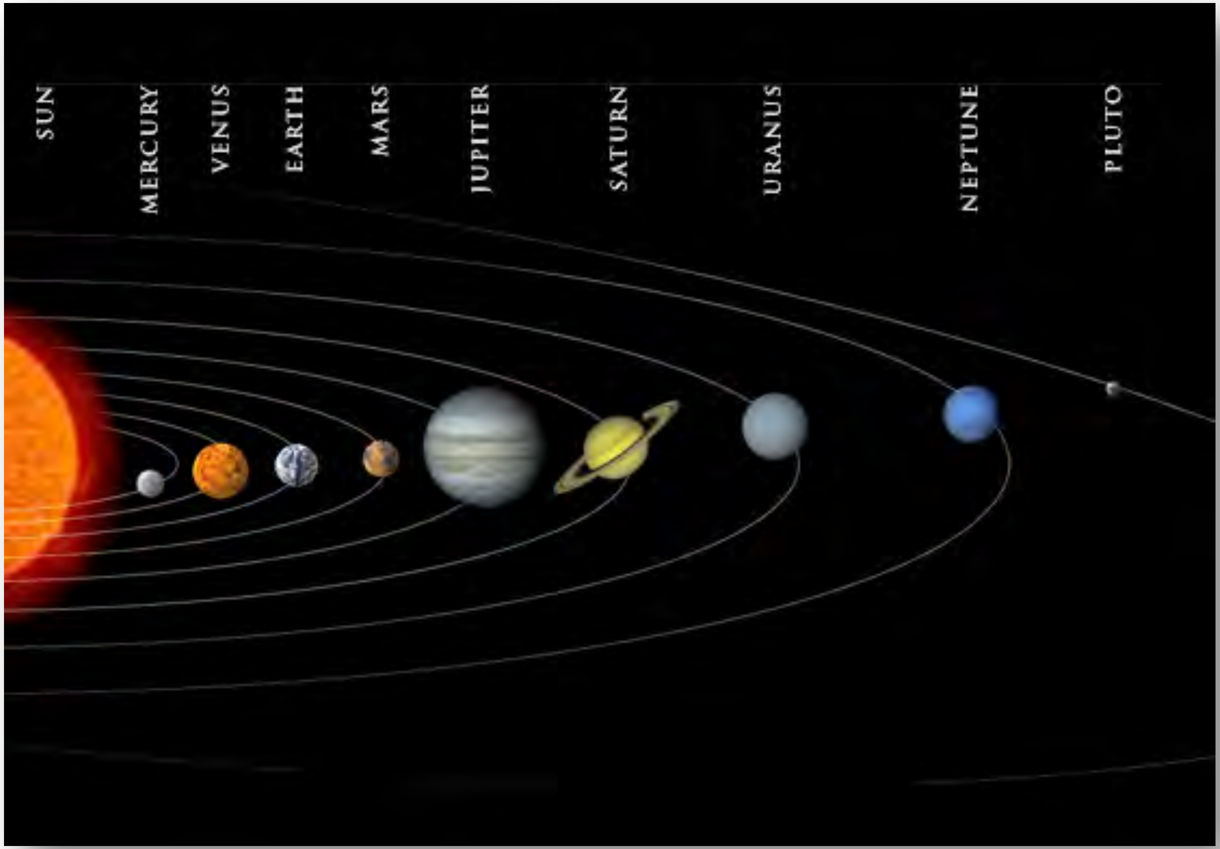
5. After a relatively short time (tens of millions of years?), our solar system looked very much as it does today.



AstronomyOnline

The nebula from which our solar system formed is known as the *solar nebula*. This theory of the formation of our solar system is known as the *solar nebula theory*.

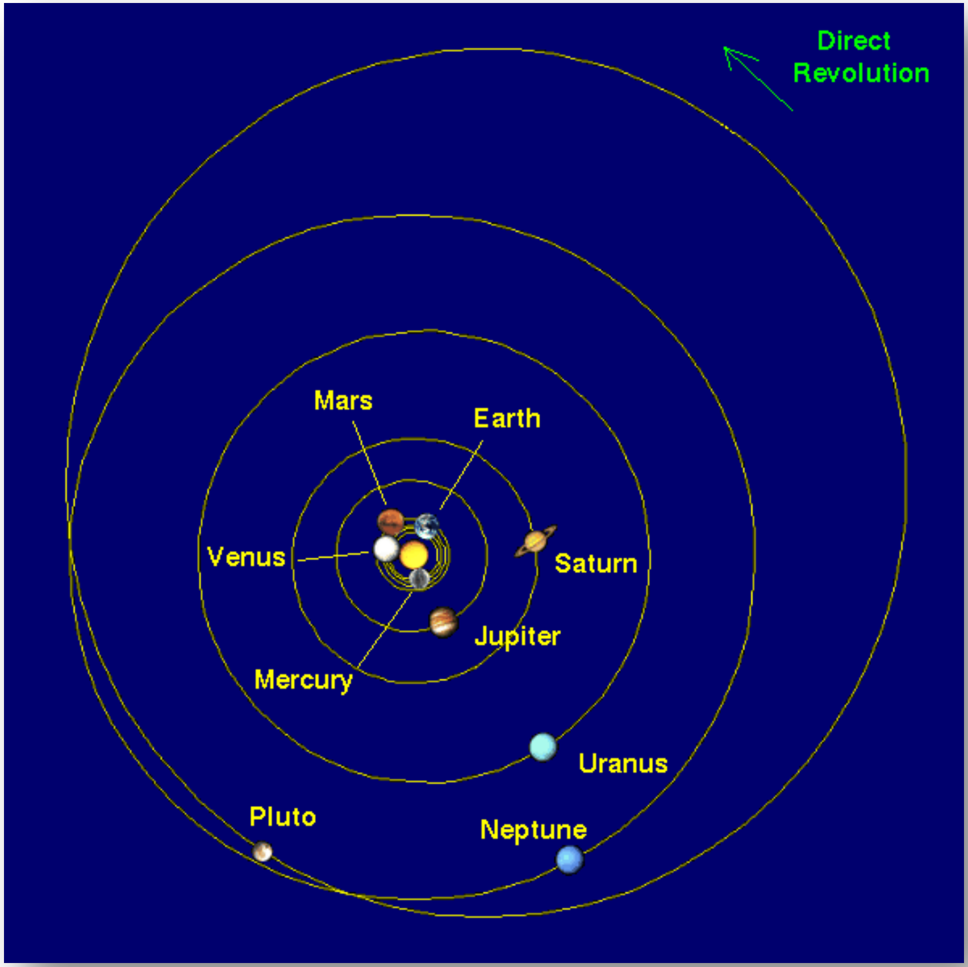
Looking at our solar system, we see that the vast majority of the mass is concentrated in the center to form our Sun.



The gas giant planets (Jupiter, Saturn, Uranus & Neptune) were able to collect larger amounts of gases and ices to form very thick atmospheres in the cooler outer reaches of the forming solar system.

The terrestrial planets (Mercury, Venus, Earth & Mars), formed from rocky material and meager atmosphere because it was too hot for the gases to remain.

The solar nebula theory for the formation of our planetary system is generally accepted. There are several observations about the solar system that are evidence in favor of this theory.



1. All of the planets revolve around the Sun in the same plane (planetary plane).
2. The Sun's rotational equator lies roughly in the planetary plane.
3. All of the planets revolve around the Sun in the same direction.
4. Planet orbits are nearly circular.

5. Most of the planets rotate in the same direction relative to the planetary plane.

6. The planets change in character from inner rocky planets to the outer Jovian planets in a manner consistent with the theory.